GUIDE TO THE STARRY HEAVENS

D. McEWAN

THE
UMBRELLA STAR MAP.

" We have not wings, we cannot soar;
But we have feet to scale and climb
By slow degrees, by more and more,
The cloudy summits of our time."

—LONGFELLOW.

St. Augustine's Ladder.

Astron.

AN EASY AND CONCISE GUIDE

TO THE

STARRY HEAVENS

WITH MAPS, KEY MAPS, SCALES AND DIAGRAMS

Arranged as a Companion

TO THE

UMBRELLA STAR MAP

AND

REVOLVING STAR DOME

FOR INSTRUCTION IN ASTRONOMY

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Member of the British Astronomical Association

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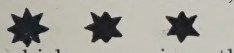
Preface.

THE Umbrella Star Map is a very useful invention for the study of Astronomy, both to the neophyte beginning his lessons and to the old astronomer interested in the development of his science. It introduces the one by gradual steps, from the elementary stage to the more abstruse problems, and to the other it affords the satisfaction of looking into his familiar field of view at any time by night or day, whether clear or cloudy, without the necessity of piecing together the sections of the starry sphere, as shown in an ordinary star atlas. The whole vault of the heavens is spread out at once, on a comparatively large scale, whenever the umbrella is put up, and the view presented is the one which most nearly corresponds with the actual standpoint of the observer looking up into the sky. Very little attention to several detailed rules connected with the hour circle on the margin is sufficient to adjust the umbrella to any particular time of observation. The stars of the first five magnitudes are depicted in their several places and constellations, indelibly printed on the cloth by a process which secures that the ordinary use of the umbrella on a rainy day will not in the least damage the impressions. A particular size and form is assigned to each magnitude—eight points being given to those of the first, seven to those of the second, six to those of the third, five to those of the fourth, and four to those of the fifth magnitude—  The number in all is over 600, which comprises the most of those plainly visible to the unaided eye in the ordinary state of the atmosphere on a clear night.

A further adaptation of the same principle has been made for the use of schools, by doing away with the frame-work and substituting a dome. The mounting is adjusted so as to give the polar inclination, the meridian, the north and south points, and the horizon; still retaining the portability of the

apparatus and allowing of its free circular movement. The teaching of local geography can be profitably combined with this artificial reproduction of the heavens, by the standpoint of the observer being represented in scale on a map spread out immediately under the dome. The connection between geography and astronomy is thus reduced to ocular demonstration.

The "Guide to the Umbrella Star Map" has been arranged so as to follow out in detail the different uses to which this form of Star Map can be put, and to give elucidation of some of the more difficult problems in the elementary study of astronomy. All the first magnitude stars in the northern hemisphere visible in the horizon of London are pointed out by name. The principal constellations are unmistakably shown by following the lines in which the ribs of the umbrella intersect them. A good deal of useful information, which everyone should know, but of which most people are ignorant, is given in the section on "Time." Diagrams of the moon and planets are introduced and general rules are indicated for following their motions in the course of the year, and for identifying them when they appear in the sky in favourable positions for observation.

A distinct step in the study of the science is provided for by inserting reduced sized diagrams of each of the eight segments of the umbrella, together with corresponding portions of the hour circle, and a scale of degrees of arc. A moveable scale is provided for more accurate measurement. Connected with these are separate catalogues of all the stars in the segment, with their Right Ascension and Declination. By means of these it is not a difficult task for any one who has mastered the first principles to construct for himself a diagram out of the catalogue, or *vice versa* to compile a catalogue out of the diagram. When this attainment has been reached by any one, he is ready to pass on to higher text books and to the celestial globe.

This system of teaching elementary astronomy and the apparatus employed has been shown to a number of astronomers, both professional and amateur, well acquainted with the difficulties connected with the teaching of the science, and qualified to speak of the merits of any system of instruction. They have invariably signified their approval of the Umbrella Star Map and its various adaptations as the letters of testimony show.

Introduction.

SEVERAL methods have been employed to bring the starry sphere into a tabulated form, to show by means of maps or diagrams the principal features of the evening sky. Different plans have been followed in constructing these, all of which have their uses for particular purposes, and the advanced pupil can make use of any one of them. Some proceed on the principle of dividing the sphere into separate portions, one showing the circumpolar stars, and four or more dealing with those lower down in the sky, in the regions North and South of the Celestial Equator. Again, the changing aspect of the sky throughout the different months of the year has been made the basis of division. Others ignore the changing aspects of the heavens and depict the star sphere with sole reference to itself, leaving the earth out of account altogether as being the cause of all the apparent motion of the heavenly bodies. The principle of the planisphere has also been followed, showing by means of a movable disc the time of rising and setting of stars for any given day or hour. The celestial globe, with its completeness in circles, measurements, and symbols, is an invaluable accessory for scientific astronomy; but for beginners it is a puzzling thing to understand, and it has the disadvantage of reversing the view of the heavens, making the spectator to look down upon the stars instead of the stars looking down upon him.

It is obvious that the more directly the natural view of the heavens can be artificially reproduced, the easier it will be to identify the positions of the stars. The interior of an umbrella fulfils this condition in a very simple way, by preserving the true relative positions of the observer and his field of view; and it not only affords scope for projecting the star map on a comparatively large scale, but it obviates the necessity of turning over the leaves of a book, by presenting the whole vault of the heavens in one view, taking it all in at a glance. It can be

adjusted to meet all the changes of apparent motion, which the earth brings about, either by its diurnal motion in twenty-four hours, or by its yearly motion in the course of its passage round the sun. The diurnal motion is provided for by the stick of the umbrella, which serves as the axis of the earth extended to the pole of the heavens, forming the centre of the twenty-four hours rotation ; and the yearly circuit of the earth in its orbit is shown by the months being marked round the edge of the umbrella. As the earth rotates on its axis the whole star sphere is passed in review every twenty-four hours : these hours are therefore marked on the circle from I. to XXIV., with the supplementary divisions into minutes. While the earth rotates on its axis it is at the same time moving in its orbit at the rate of $18\frac{1}{2}$ miles a second, which brings it to the same point in the heavens four minutes less than twenty-four hours every night ; and these minutes accumulating night after night amount to two hours in a month and twenty-four hours in the year. This is the problem to be solved in projecting star maps, viz., how to make them keep pace with the earth from month to month, so as to show the positions of the stars in their apparent motions all the year round. The umbrella lends itself to an easy solution of this problem for any night in the year and any hour in the night.

Two points in the heavens, which shall be constant, always the same, must be determined, and to these every variable succession of movements is to be referred. One of these is not far to seek—the pole star, which although not absolutely situated at the true pole is near enough to that point for purposes of general observation. The other fixed point must be on the circumference as the first is in the centre, and it has been determined by common consent from time immemorial to be "the first point of Aries," having the sign of the Ram's horns. Originally, when this point was fixed two thousand years ago, it marked where the sun crossed the equator at the vernal equinox on the 21st March, and the point of crossing was then in the constellation of the Ram, but owing to a movement called the precession of the equinox, that equinoctial point has moved away from the constellation. It is a very slow movement, only 3.3 seconds in the year, but in the course of two thousand years these seconds have accumulated to about two hours. This

is sufficient to displace the equinox one whole sign of the Zodiac, and "the first point of Aries" is now in the constellation of Pisces. This starting point is now in Pisces, but the name "first point of Aries" is still applied to it by time-honoured usage, and the sign of the horns ♈ is placed there. The signs with their symbols are not therefore to be confounded with the constellations of the same name, for the symbols are all set down in regular monthly rotation from that of the Ram's horns which indicates the first point of the sign Aries. This fixed point in the circumference is not marked by any conspicuous star as the polar point is, but its position is made clear on the umbrella by the sign of the horns ♈ being placed at the XXIVth hour, which is also the beginning of the hour circle : a line from the pole to this mark will pass through the first point of Aries.

To place the umbrella in position to show how the stars are situated at any particular time the following process has to be observed :—(1) Ascertain approximately the meridian of the place, *i.e.*, the direction of due south ; (2) hold the umbrella with the day of the month on this point—the name is printed about the middle of the month. This will give the position of the stars for midnight on the date in question ; if it is required to know their position three hours earlier—say at nine o'clock—(3) turn the umbrella to the left three hours round and put that point on the meridian : it will be found that the stars in the heavens will be just as shown on the umbrella. If the position is wanted after midnight, say at three o'clock in the morning, the umbrella must be turned the reverse way—three hours to the right. Again, when the stars cannot be seen in the daytime because of the brightness of the sun, their positions can be ascertained by the help of that great luminary. Ascertain from an almanac the particular sign the sun happens to be in at the time, hold up that sign to the sun pointing the stick towards the north, and his brightness will shine through the cloth like a shaded lamp, when the positions of the stars* will be truly indicated in broad daylight on the interior surface of the umbrella. This process may

* If the stars are to be projected into their true positions in the sky, the position of the eye will have to be changed and the eye moved along the stick of the umbrella to suit the declination of the star.

be reversed at night to find the position of the sun, by setting the umbrella to show the stars on the day and hour, as before described, ascertaining from an almanac or otherwise, the sign occupied by the sun, which he enters about the 21st or 22nd of each month, and the finger may be put upon the exact spot in the particular constellation although he may have set in the west hours before. Still further, an interesting experiment may be made on a clear starry night, by setting the umbrella, as before, to the actual position of the stars, and illuminating the interior with a lamp; they will be found to correspond star for star, and if the names of the principal ones have already been learned and their places found on the cloth sphere, there will be no difficulty in identifying them on the broad expanse of the vault above. This has been proved with a class of school children. To their great delight they were able to point out the first magnitude stars then visible, from observing them on the umbrella, and to learn their names, not from the columns of a table, but from their places in their true homes in the family constellations.

Although many of the stars have proper names of their own, yet it is found to be more suitable to distinguish them in some more categorical way, as by the letters of the Greek alphabet, or the numbers of some star catalogue, ranging them by these means within the constellations to which they belong. By employing the letters of the Greek alphabet, twenty-four stars in each group may be designated, and that is going a good way in the direction of star study.

THE GREEK ALPHABET.

α	Alpha.	ι	Iota.	ρ	Rho.
β	Beta.	κ	Kappa.	ς	Sigma.
γ	Gamma.	λ	Lambda.	τ	Tau.
δ	Delta.	μ	Mu.	υ	Upsilon.
ϵ	Epsilon.	ν	Nu.	ϕ	Phi.
ζ	Zeta.	ξ	Xi.	χ	Chi.
η	Eta.	o	Omicron.	ψ	Psi.
θ	Theta.	π	Pi.	ω	Omega.

The positions of the individual stars are reckoned, like the latitude and longitude of a town, along two circles at right angles

to one another. The first measurement is called the Right Ascension and is taken on the celestial equator or equinoctial, which is just the equator of the earth extended to the heavens. The complete circle is divided into 360 degrees or twenty-four hours, and the constructive "first of Aries" is the beginning. The Right Ascension is most easily measured by the time which elapses between the first point of Aries and the star crossing the meridian of the observatory; it can be converted into degrees at 15 degrees to the hour. How high or low it may be on the meridian is called its Declination, and that is measured in degrees of arc from the equator. In the series of diagrams each segment of the umbrella is given separately; the Declination degrees are given on the edges, from nothing (zero) at the equinoctial to 90° at the pole, which is called north Declination, and from the equinoctial downward to about 47°, and this is called south Declination. The Right Ascension is given in time on the hour circle round the circumference. In order to find any particular star in the section, first ascertain its Right Ascension (R.A.) from the catalogue, and note the hour and minute in the time circle, the star will be on a line between that point and the Pole; how far up or down on that line will be found in the Declination column (Decl.).

CHAPTER I.

THE STARS.

THE Stellar Universe is a vast region utterly beyond the grasp of the finite mind; the stars we see only serve to bring us some idea of the depths of space beyond them. The distances are so great that miles shrink into utter insignificance when they are employed, the number of figures to be set in a row become so clumsy that some other means of expressing the distances becomes absolutely necessary. Three such measuring lines have been adopted, each suited for the particular use it is intended to serve. First, there is the radius of the earth, 3956 miles: this is used for nearer bodies such as the Moon, Mercury and Venus. Next there is the radius of the earth's orbit, which is the distance of the sun, 93 millions of miles: this is called the "Astronomical Unit," and it is used in measuring the distances of the outer planets, Jupiter, Saturn, Uranus and Neptune. The third unit of measurement is the "light-year," that is, the distance light travels in a year going at the rate of 186,000 miles per second, which amounts to 63,000 astronomical units, or roughly, six billions* of miles. The nearest fixed star measured or measurable by this unit is computed to be four of these light years distant: it is Alpha of the Centaur constellation, while the Pole Star is forty-seven light-years away from the earth. It is supposed that all the stars spread out in the region of the sky we see are but a single star-cluster of which our sun is one, the Milky Way including the orbits in which they all move, and that there are many such constituent clusters making up the whole stellar universe. Whether this theory be right or not it helps the mind to grasp at a reasonable conception of a probable plan of the universe, and for want of a better idea of it this one may be entertained.

The first casual view of the stars gives the impression that they are strewn about in a very indiscriminate fashion, thicker here and thinner there and after no manner of order. This puzzling profusion may have suggested the arbitrary groupings which

* According to the English system of notation, a billion=(a million)^2=10^{12} and a trillion (a million)^3=10^{18}.

have been made into constellations, laying hold of certain apparent connections and giving them a name. There are forty-eight constellations which have come down from ancient times, and some modern ones have been added. The most ancient of all are the twelve of the Zodiac already mentioned. These signs are prehistoric in their origin and are found sculptured in the ancient ruined temples of Egypt. They are referred to in the book of Job (xxxviii. 32) under the name of Mazzaroth, along with the Pleiades, Orion, and Arcturus; and it is no doubt these same twelve constellations which are spoken of in the XIXth Psalm as being "a tabernacle for the sun." At any rate they are very closely associated with the sun in that way, as he is always in one or other of them. It is their connection with the sun, in this way, that gives them their importance. In themselves they have no specially striking features, so far as known. Most of the other groups have more attractions as objects of interest in the sky.

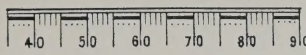
In endeavouring to trace out the constellations the Umbrella Star Map affords valuable aid, being divided into segments by means of the ribs; and the ribs themselves are specially useful in pointing out the various groups they pass through, as they bend from the centre downward, from the pole to the hour circle at the outer edge. Beginning at the first point of Aries, the rib nearest to that comes down midway between XXIV. and I. hour on the circle; and the second one, which encloses the segment, intersects three hours to the left, between III. and IV.

The region of the circumpolar stars is the first to which the people living in the latitude of the British Isles should turn their attention, because they are all to be seen on every clear night in any season of the year; they never sink below the horizon, though some of them may come very near it. The northern heavens have the advantage of appearing as a large circular dome, the pole star being situated, not at its centre, the zenith of the observer, but at a lower and more convenient angle.

The circumference of the disc is drawn with a radius of fifty-five degrees*, and within it the stars revolve in solemn, silent nightly procession. They are all set down to scale, in the diagram enclosed in a framing border, which requires some

* For London the radius should be limited to about $51\frac{1}{2}°$.

NORTH CIRCUMPOLAR STARS.

Scale of  degrees.

attention and calls for explanation. A good understanding of the principle of its construction leads to an easy deciphering of seeming complications in all the other segments. In the series of concentric circles the first shows the hours of the ordinary clock in two twelves for day and night, with short dashes and spaces to mark the quarters. In the second circle the names of the months are inserted in relation to the vernal equinox on 21st March, which coincides with "the first point of Aries," as indicated by the Ram's horns outside the circles. This is the starting point for all stellar observation. The third space encloses several circles divided up into detached portions, with the twenty-four hours of the sidereal clock on the outer circumference, beginning at the first point of Aries where the "XXIV" is placed. The longer curves and intervening spaces stretching from hour to hour represent fifteen degrees of arc, which being repeated twenty-four times completes the circle of three hundred and sixty degrees. The shorter curves and spaces divide the hours into three portions of twenty minutes each. The small declination scale given at top of page 17 may be copied on the edge of a piece of cardboard, and each star measured off by its declination from the pole to the hour circle and its right ascension, as marked round the circumference from the first of Aries. The symbols of the twelve signs are given outside the circles at the places where the sun enters each sign* in turn, which roughly corresponds with the 21st of each month. The points of the compass have no place when the North Pole is the centre, the whole circumference is south; and east and west are different directions for any radius. In following out the constellations these are not required, as the Umbrella Star Map has to be set in many different positions so as to show the aspect of the sky at any particular time, and this is determined by other data, as explained on page 11, and more fully demonstrated in the table given on page 70. This region of the heavens has its boundary fairly well marked out by a circle of constellations—Andromeda, Perseus, Auriga, Canes Venatica, Bootes, Hercules, Lyra and Cygnus, and higher up it includes Cassiopeia, Ursa Major and Ursa Minor, Draco, and Cepheus. Near the boundary line also are situated several prominent stars, as Algol, Capella, Vega, and Aridid at the dividing of the Milky Way

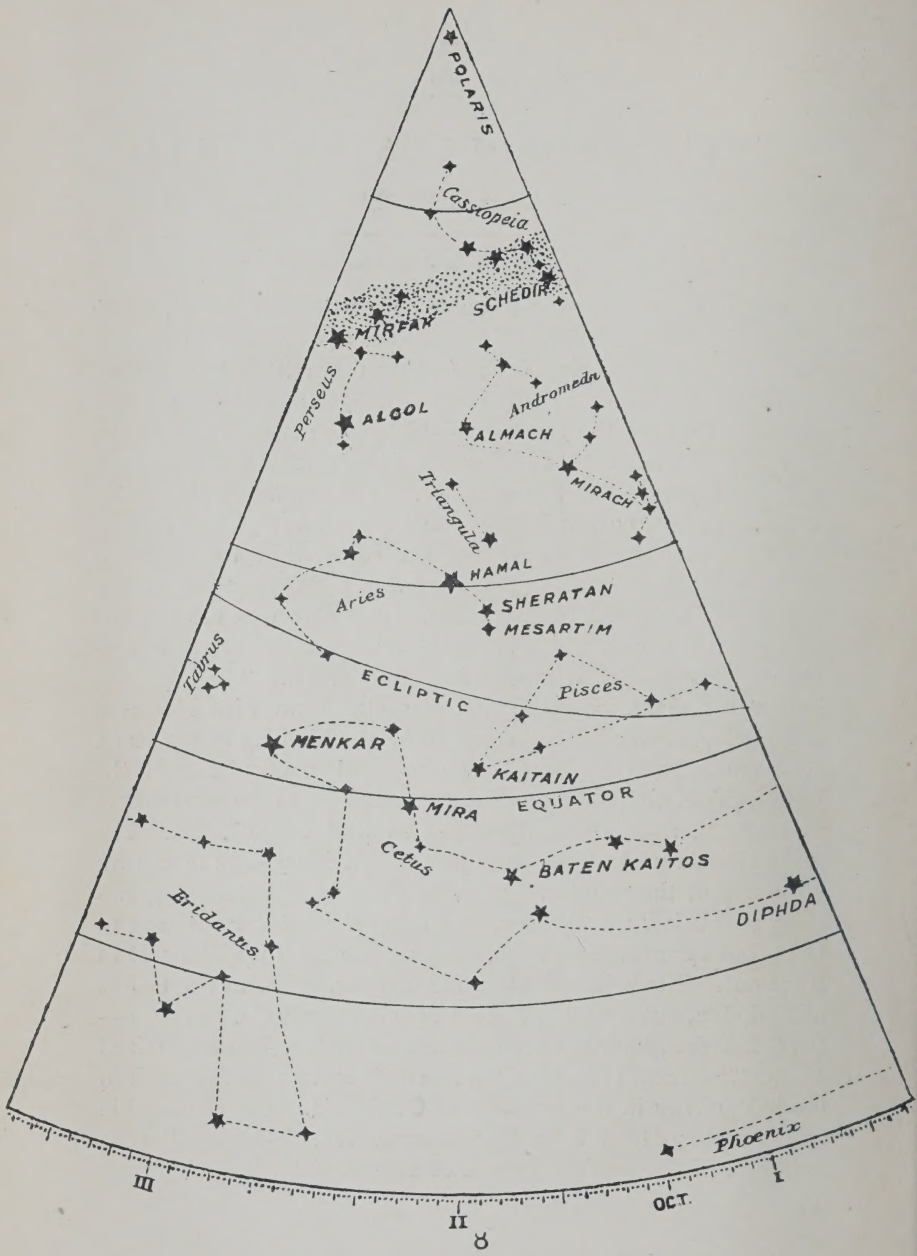
* See top of page 11.

CHAPTER II.

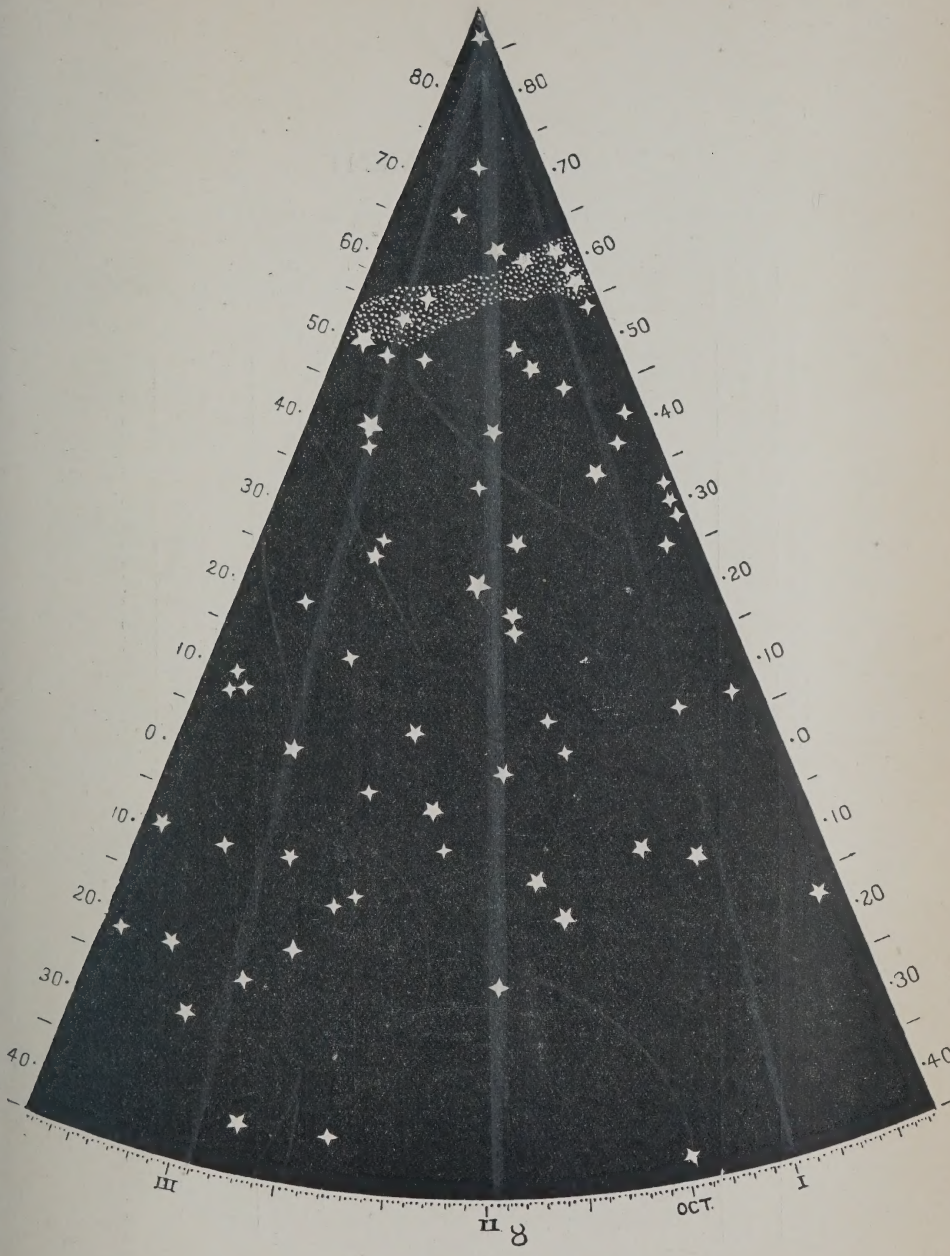
THE UMBRELLA STAR MAPS.

DESCRIPTION OF SEGMENT I.

The first rib on leaving the pole passes through the W, which is the chief characteristic of Cassiopeia, the distance in degrees from the equator being 60° ; further down it divides Andromeda into two almost equal portions at 30° and at the equator it comes between the two fishes—Pisces, the twelfth sign of the Zodiac ; and finally about 10° south of the equator it goes through a part of Cetus—the Sea Monster. The second rib intersects Perseus at 50°, covers part of the Pleiades at 25°, and crosses Eridanus, the river, about 10° south. Within this segment Aries is situated, with the star Hamal at 25° declination, on the line of II. hours Right Ascension. This star was the original first point of Aries, which shows how far the movement in precession has carried it round from the present "first point." Two other stars, Sheratan and Mesartim form with Hamal a dog-leg angle, which is supposed to be the hind leg of the Ram. Andromeda has a long sweep of four stars almost equi-distant, the last of which, Alpheratz, forms the upper corner of the great square of Pegasus, and is sometimes put in that constellation. The great Nebula of Andromeda is just on the inner edge of the rib 40° north of the equator. Cetus is a large and extended group lying just below the equator, measuring about 80° from head to tail ; but because of its length and zig-zag form it is difficult to trace out. The principal stars are Menkar, Mira, Baten Kaitos and Diphda, but none of them are of first magnitude. Perseus—the deliverer of Andromeda from the sea monster—is characterized by the "Segment of Perseus," a line of four stars curving up into the Milky Way in the direction of Cassiopeia. The remarkable variable star Algol, is in this constellation. The small constellation of Triangulum is one of ancient date, lying between Andromeda and Aries.



KEY TO SEGMENT I.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I

SEGMENT I.

STARS IN SEGMENT I.

Asterisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	Name of Constellation.	Magnitude.	R.A.			Decl.	
1	ζ	Cassiopeiae, ...	3.7		31	N	53	22
*2	π	Andromedae, ...	4.4		31	N	33	12
3	ϵ	,, ...	4.6		33	N	28	48
4	δ	,, ...	3.4		34	N	30	20
5	α	Cassiopeiae (*Schedir*), ..	v. 2.2 / 2.8		35	N	56	1
6	β	Ceti (*Diphda*), ...	2.1		38	S	18	29
7	ζ	Andromedae, ...	4.4		42	N	23	45
8	δ	Piscium, ...	4.6		43	N	7	4
*9	η	Cassiopeiae, ...	2.3		43	N	57	19
10	ν	Andromedae, ...	4.4		44	N	40	34
11	γ	Cassiopeiae, ...	2.3		51	N	60	12
12	μ	Andromedae, ...	3.9		51	N	37	59
13	ϵ	Piscium, ...	4.5		58	N	7	23
14	η	Ceti, ...	3.6	1	3	S	10	41
15	β	Andromedae (*Mirach*), ..	2.2	1	4	N	35	7
16	ξ	Andromedae, ...	4.9	1	16	N	45	2
17	θ	Ceti, ...	3.8	1	19	S	8	39
18	δ	Cassiopeiae, ...	2.8	1	19	N	59	44
19	γ	Phœnicis, ...	3.4	1	24	S	43	47
*20	α	Ursae Minoris (*Polaris*), ..	2.2	1	25	N	88	48
21	η	Piscium, ...	3.7	1	26	N	14	51
22	51	Andromedae, ...	3.7	1	32	N	48	8
23	ν	Piscium, ...	4.7	1	36	N	5	0
24	54	Andromedae, ...	4.2	1	37	N	50	12
25	τ	Ceti, ...	3.6	1	39	S	16	26
26	o	Piscium, ...	4.4	1	40	N	8	41
27	ϵ	Cassiopeiae, ...	3.6	1	47	N	63	12
28	ζ	Ceti (*Baten Kaitos*), ..	3.8	1	46	S	10	47
29	α	Trianguli, ...	3.6	1	47	N	29	7
*30	γ^1	Arietis (*Mesartim*), ...	5.0	1	48	N	18	48
31	β	Arietis (*Sheratan*), ...	2.8	1	49	N	20	21
32	50	Cassiopeiae, ...	4.1	1	55	N	71	58
33	υ	Ceti, ...	3.8	1	55	S	21	31
*34	α	Piscium (*Kaitain*), ...	4.0	1	57	N	2	18
*35	γ^1	Andromedae (*Almach*), ..	2.2	1	58	N	41	52
36	α	Arietis (*Hamal*), ...	2.0	2	1	N	23	1
37	β	Trianguli, ...	3.1	2	3	N	34	32
38	67	Ceti, ...	5.5	2	12	S	6	50
39	o	,, (*Mira Ceti*), ..	var.	2	14	S	3	23
*40	ι	Cassiopeiae, ...	4.6	2	21	N	66	59
41	ξ^2	Ceti, ...	4.4	2	23	N	8	2
42	δ	,, ...	4.1	2	34	S		4

No.	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
43	ϵ	Ceti, ...	5.0	2	35	S	12	16
44	θ	Persei, ...	4.2	2	37	N	48	49
45	ι	Eridani, ...	4.2	2	36	S	40	15
46	π	Ceti, ...	4.3	2	39	S	14	14
47	39	Arietis, ...	4.6	2	42	N	28	51
48	η	Persei, ...	3.9	2	43	N	55	30
49	41	Arietis, ...	3.8	2	44	N	26	52
50	σ	,, ...	5.5	2	46	N	14	41
51	τ^2	Eridani, ...	4.8	2	46	S	21	23
52	η	,, ...	4.0	2	51	S	9	16
*53	θ	,, ...	2.6	2	54	S	40	40
54	γ	Persei, ...	3.1	2	58	N	53	8
55	α	Ceti (*Menkar*), ...	2.7	2	57	N	3	43
56	τ^3	Eridani, ...	4.1	2	58	S	23	59
57	ρ	Persei, ...	3.7	2	59	N	38	28
58	β	,, (*Algol*), ...	v. 2.2 / 3.7	3	2	N	40	35
59	ι	Persei, ...	4.1	3	2	N	49	15
60	δ	Arietis, ...	4.5	3	6	N	19	22
61	12	Eridani, ...	3.8	3	8	S	29	20
62	ζ	,, ...	4.8	3	11	S	9	10
63	τ^4	,, ...	3.8	3	15	S	22	6
64	α	Persei (*Mirfak*), ...	1.9	3	17	N	49	31
65	θ	Tauri, ...	4.5	3	17	N	8	41
66	o	,, ...	3.8	3	19	N	8	41
67	ξ	,, ...	3.8	3	22	N	9	24
68	ϵ	Eridani, ...	3.7	3	28	S	9	46
69	τ^5	,, ...	4.2	3	29	S	21	56

DESCRIPTION OF SEGMENT II.

The third rib intersects a portion of Gemini about 20° north, and about the same distance south it runs into Canis Major near Sirius, the dog-star. This segment is rich in constellations and it has four first magnitude stars, viz., Capella, Aldebaran, Betelgeux and Rigel. Auriga, the charioteer, is well marked out by Capella, and her companion star, Menkalinan, about 8° to the left. There are also the three kids of the goat forming a very correct isosceles triangle quite near to Capella, who is supposed to be their mother. Taurus, the bull, is situated directly under Auriga, with Aldebaran, the eye of the bull, shining with subdued lustre. The two horns stretch out in front with a star at each tip, Nath being the upper of the two. The Pleiades are a glittering group, sloping in the opposite

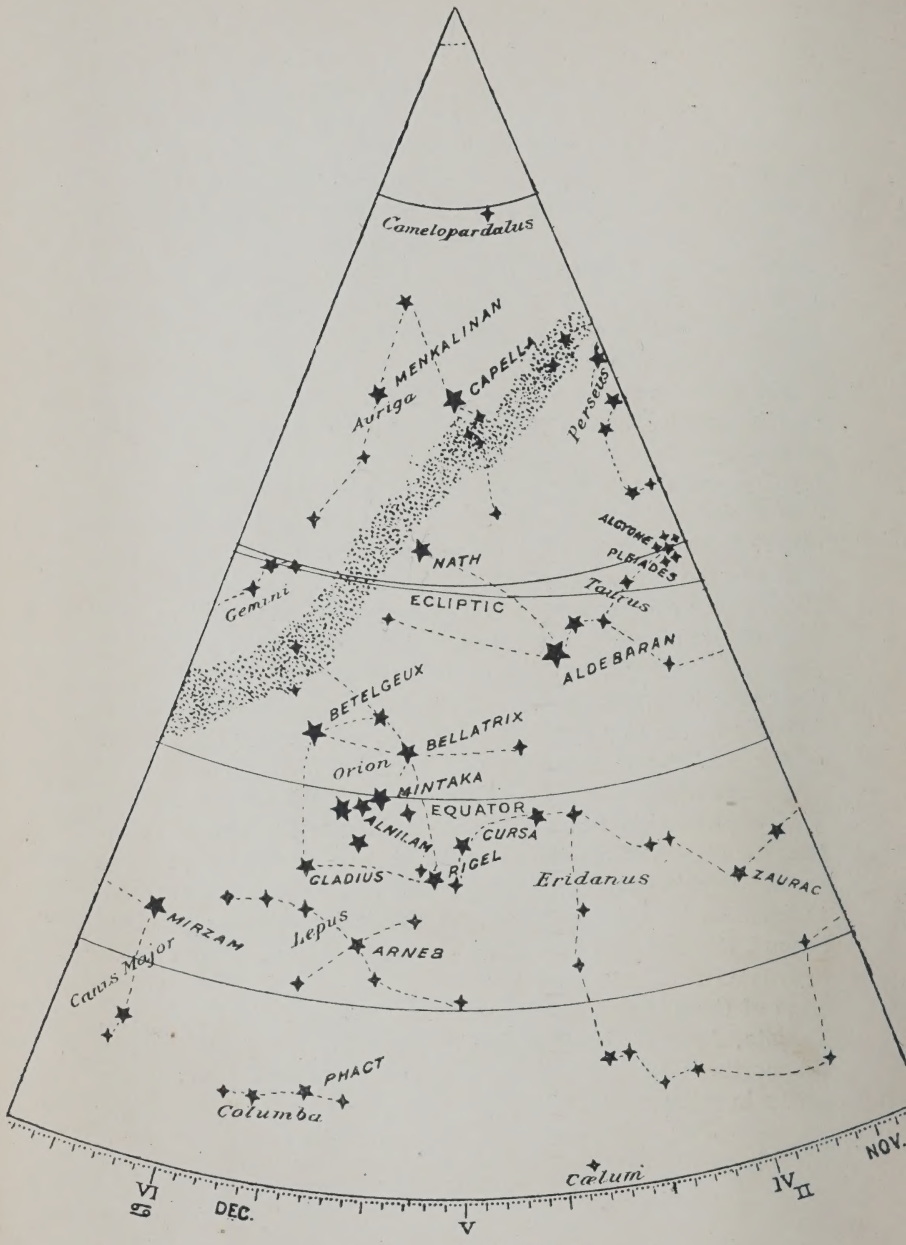
direction from the horns: their principal star is Alcyone. Orion, a well known and well marked constellation, is important as marking out the place of the celestial equator which passes Mintaka, the upper star of the belt. The right shoulder is adorned with a first magnitude star, Betelgeux, and the left shoulder one of second magnitude, Bellatrix. The right knee is marked by Gladius and the left foot by Rigel. These four stars form a parallelogram, which gives to the whole group a characteristic outline, with the belt as a central feature equi-distant from the four points. The belt is nearly 3° across and is sometimes called the ell-wand. In it the sword is placed, also consisting of three stars, the middle one being in the great Nebula of Orion. Two small constellations are directly under Orion, Lepus, the hare, and Columba, the dove. Eridanus, the river, rises near the right foot of Orion, and flows westward for a long distance, and finally disappears below the horizon. The Cameleopard is high up in this section, but of no particular importance. It is of modern invention intended to account for a large empty space otherwise unoccupied.

Orion may fairly lay claim to pre-eminence among the constellations, not even excepting the Plough, because of its striking and distinct figure in outline. It is a very well defined group in the sky, though it is not in the least like the mythological hero whose name it bears. Even to the naked eye it is an attractive sight during the month of March in the southern sky, and in the telescope it increases in interest as the magnifying power is increased. The closer it is examined in this way the more does it yield up its intrinsic treasures of stellar magnificence. There are two double stars—Rigel in the lower right hand corner, and Mintaka, the upper star in the belt. There are three triple stars—Zeta the lower star of the belt, Sigma the upper star of the sword, and Iota the lower star of the sword, while the middle star of the sword, Theta is a quadruple star in the form of a trapezium (a figure of four unequal sides). This multiple star still further introduces the observer to the great Nebula in Orion, which is the finest in the heavens among a multitude now numbered by tens of thousands. Theta is set "in the thick" of this Nebula, and thus furnishes a scale of comparison to show its scope. It extends by actual measure-

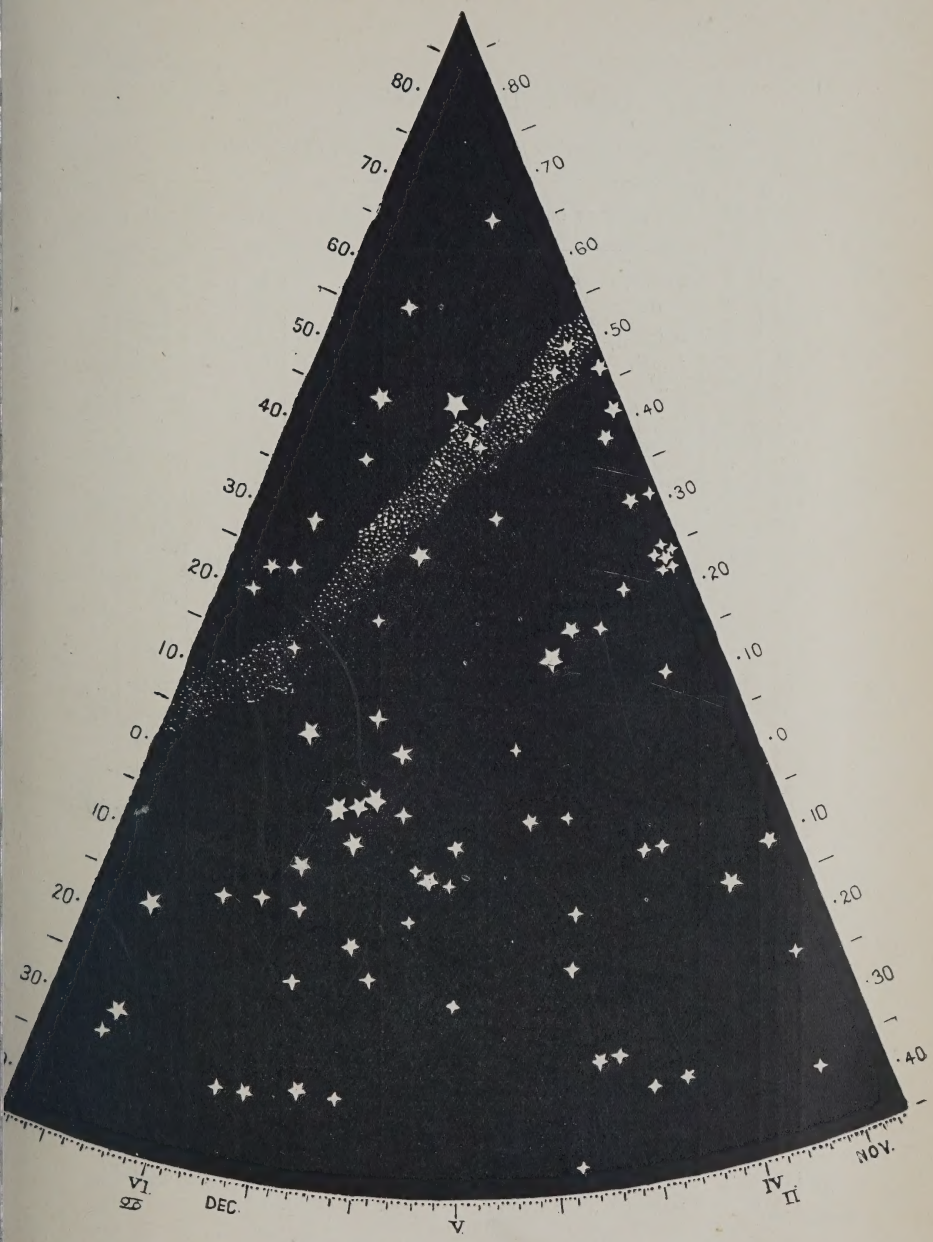
ment to several square degrees, which is a vast area considering that its distance from the earth is not less than four light years and may be a great deal more. If the whole range of the solar system included in the orbit of Neptune be taken as a known unit of size, six thousand millions of miles, it would form but a small part of this great Nebula. A recently published photograph shows this Nebula to be a veritable creating laboratory on a gigantic scale. It appears as an enormous mass of fiery matter broken in contour by vacant cavities, with large detached portions thrown off, some cloud-like of no definite shape, but others in well developed circular discs of various sizes and sending out brilliant rays.

The Pleiades are an example of star clusters, a very numerous class of stellar bodies more or less densely packed together, so closely indeed in many cases that they can only be resolved into separate stars by telescopes of high magnifying power. The Pleiades cluster is one of the least compact among them, some of the separate stars being discernible by the naked eye. Seven of the largest may be easily counted, but with a telescope the number coming into distinctness grows rapidly until nearly a hundred shine out. The telescope looks into the sky with a penetrating glance, but the camera leaves it far behind in its deep, searching, steady gaze. The photographic plate brings out features in the sky formerly unknown, and among these many of the Pleiades are found to be adorned with appendages of streamers which can only be likened to a permanent Aurora. This constellation has a glittering brilliance far beyond what the magnitudes of the stars composing it would warrant, so that it must have a setting in a background which acts like a reflector to increase its shining power. A poetic interest has gathered around the Pleiades ever since the days of Job, when he was instructed in the "sweet influences" of their symbolic value. Nine of them have names—Alcyone, Merope, Celaeno, Electra, Tayjeta, Astrope, Maia, Pleione, and Atlas. They are seen in the northern hemisphere most of the year, except about six weeks in midsummer, when they dip below the horizon.

> "There is a time, when forty days they lie
> And forty nights, concealed from human eye;
> But in the course of the revolving year,
> When the swain sharps the scythe they re-appear."



KEY TO SEGMENT II.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SEGMENT II.

STARS IN SEGMENT II.

Asterisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	Name of Constellation.	Magnitude.	R.A.			Decl.	
70	δ	Persei, ...	3.2	3	36	N	47	29
71	o	,, ...	5.0	3	36	N	33	39
72	ν	,, ...	4.0	3	38	N	42	16
73	δ	Eridani, ...	3.7	3	38	S	10	4
74	17	Tauri, ...	3.8	3	39	N	23	49
75	19	,, ...	4.4	3	39	N	24	9
76	η	,, (*Alcyone*), ...	3.0	3	41	N	23	48
77	τ^1	Eridani, ...	4.8	3	42	S	24	10
78	27	Tauri, ...	3.8	3	43	N	23	45
79	υ^2	Eridani, ...	4.1	3	46	S	36	29
*80	ζ	Persei, ...	3.1	3	48	N	31	36
*81	ϵ	,, ...	3.0	3	51	N	39	44
82	γ^1	Eridani (*Zaurac*), ...	3.0	3	53	S	13	46
83	λ	Tauri, ...	3.6	3	55	N	12	13
84	λ	Persei, ...	4.5	3	59	N	50	5
85	A^1	Tauri, ...	4.6	3	59	N	21	49
86	μ	Persei, ...	4.2	4	7	N	48	10
87	o^1	Eridani, ...	4.1	4	7	S	7	4
88	o^2	,, ...	4.5	4	31	S	7	48
89	υ^4	,, ...	3.3	4	14	S	34	1
90	δ^1	Tauri, ...	4.0	4	17	N	17	19
91	υ^5	Eridani, ...	4.9	4	20	S	34	14
92	ϵ	Tauri, ...	3.7	4	23	N	18	58
93	υ^6	Eridiani, ...	4.4	4	29	S	29	57
*94	α	Tauri (*Aldebaran*), ...	1.0	4	30	N	16	19
95	ν	Eridani, ...	4.1	4	31	S	3	32
96	υ^7	,, ...	3.8	4	31	S	30	45
97	53	,, ...	3.9	4	33	S	14	28
98	54	,, ...	4.5	4	36	S	19	55
99	α	Caeli, ...	4.6	4	38	S	42	4
100	μ	Eridani, ...	4.3	4	40	S	3	25
101	α	Camelopardi, ...	4.4	4	44	N	66	10
102	π^1	Orionis, ...	3.3	4	44	N	6	47
103	ι	Aurigae, ...	2.7 v.	4	50	N	33	1
104	ϵ	,, ...	3.0	4	55	N	43	41
105	ζ	,, ...	4.0	4	55	N	40	56
106	η	,, ...	3.3	4	59	N	41	6
107	ϵ	Leporis, ...	3.3	5	1	S	22	29
108	β	Eridani (*Cursa*), ...	2.9	5	3	S	5	12
109	λ	Eridani, ...	4.4	5	4	S	8	53
110	α	Aurigae (*Capella*), ...	0.2	5	9	N	45	54
*111	β	Orionis (*Rigel*), ...	0.3	5	10	S	8	18
112	τ	Orionis, ...	3.6	5	13	S	6	57
113	λ	Leporis, ...	4.3	5	15	S	13	16
114	η	Orionis, ...	3.5	5	19	S	2	28

No.	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
115	γ	Orionis (*Bellatrix*), ...	1.9	5	20	N	6	15
116	β	Tauri (*Alnath*), ...	1.9	5	20	N	28	31
117	β	Leporis, ...	3.0	5	24	S	20	49
118	δ	Orionis (*Mintaka*), ...	v. 2.2 / 2.7	5	27	S		21
119	α	Leporis (*Arneb*), ...	2.7	5	28	S	17	53
120	ϵ	Columbae, ...	3.8	5	28	S	35	53
*121	λ	Orionis, ...	3.5	5	29	N	9	52
*122	ι	,, ...	3.0	5	30	S	5	58
123	ϵ	,, (*Alnilam*), ...	1.8	5	31	S	1	15
124	ζ	Tauri, ...	3.0	5	32	N	21	5
*125	ζ	Orionis, ...	2.0	5	36	S	1	59
126	α	Columbae (*Phact*), ...	2.7	5	36	S	34	7
*127	γ	Leporis, ...	3.8	5	40	S	22	28
128	ζ	,, ...	3.7	5	42	S	14	50
129	κ	Orionis, ...	2.2	5	43	S	9	41
130	β	Columbae, ...	2.9	5	47	S	35	47
131	α	Orionis (*Betelgeux*), ...	1.0 / 1.4	5	50	N	7	23
132	δ	Aurigae, ...	3.3	5	51	N	54	16
133	η	Leporis, ...	3.7	5	52	S	14	10
134	β	Aurigae (*Menkalinan*), ..	2.1	5	52	N	44	56
135	θ	Aurigae, ...	2.7	5	53	N	37	12
136	γ	Columbae, ...	4.1	5	55	S	35	16
137	ν	Orionis, ...	4.4	6	2	N	14	46
138	θ	Leporis, ...	4.6	6	1	S	14	55
139	κ	Aurigae, ...	4.5	6	9	N	29	31
140	η	Geminorum, ...	v. 3.2 / 4.2	6	9	N	22	31
141	ζ	Canis Majoris, ...	3.0	6	16	S	30	1
142	μ	Geminorum, ...	3.2	6	17	N	22	33
143	β	Canis Majoris (*Mirzam*), ..	2.0	6	18	S	17	54
144	3	Canis Majoris, ...	4.1	6	18	S	33	22
145	ν	Geminorum, ...	4.0	6	23	N	20	16

EXERCISE.

Draw the triangular outline of Segment II. in diagram form, and set down in their proper positions the principal stars in Orion, thus :—

Get the Right Ascension from the catalogue for each star, and mark it off on the hour circle. Draw dotted lines from these up to the pole, and measure off the declination by scale. The intersection of the two measurements will be the true places of the stars.

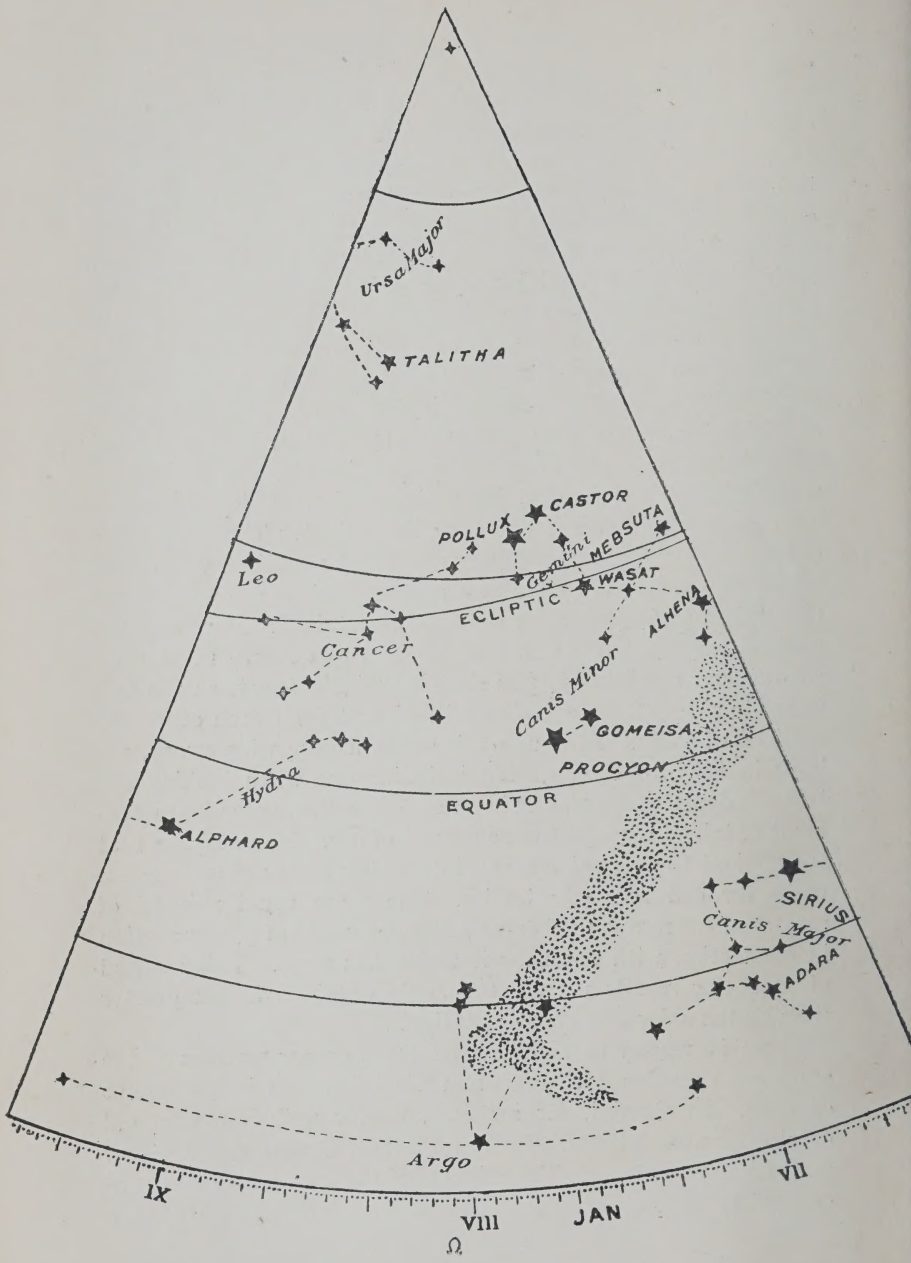
DESCRIPTION OF SEGMENT III.

The fourth rib which comes down at Right Ascension, nine hours thirty minutes, cuts through the fore paws of the great bear; at 20° north cuts off the point of the sickle in the lion; and about the same distance south it goes through the neck of Hydra. Within this segment are two of the Zodiacal constellations, Cancer, the crab, and Gemini, the twins. They are, of course, on the ecliptic or sun's path, and they fill up the portion of that circle contained in this division of the sphere. Cancer is chiefly remarkable for being the ancient northern boundary of the Tropics, when the name was given to the circle, which has ever since remained with it, though with the precessional movement the higher solsticial point is now in the neighbour constellation Gemini, the best guide to which are the twins Castor and Pollux. Although these two adjacent stars are always written in this order with Castor first, yet Pollux is the brighter of the two and is classed as a first magnitude star. The ancient Phœnician mariners seem not only to have observed the stars for purposes of navigation, but also to have borrowed their names for their ships (as in Acts xxviii. 11). Other stars in Gemini are Alhena just at the rib, and Mebsuta also on the rib about 10° higher up, and Wasat which forms a triangle with the twins themselves. Canis Minor and Canis Major are another pair of neighbour constellations situated on each side of the Milky Way and equi-distant from it. They have each a star of first magnitude to distinguish them, Canis Minor, the little dog, has Procyon, and Canis Major, the great dog, has Sirius. These two with Betelgeux, Orion's shoulder piece, form a large equilateral triangle, which serves to point out these three adjacent groups in this part of the sky. Sirius was long supposed to be the nearest neighbour to our Sun, simply because it is the brightest star in the sky, but that position is now assigned to Alpha in Centaur by actual measurement, and Sirius has now only the fourth place, being 8 light-years distant. Away down at the boot-like ending of the Milky Way is the ancient group called Argos, the ship. Canopus is its brightest star, but too low down on the horizon to be seen.

Sirius calls for attention because it represents a class of stars in which proper motion can be detected. It is a double star

of the type called Binary, the two composing the pair being organically connected and not simply appearing as two in the line of vision. There is a large number of double stars which only appear so because they come into line with the eye of the observer on the earth, the one being situated behind the other, but further embedded in the depth of space. The Binary stars, on the other hand, have a controlling power over each other, and revolve around their common centre of gravity. In order to determine this a periodical system of observation is carried on for a series of years and the angles of difference measured with precision. Sirius was subjected to this process from about the middle of last century, and was found to be moving in an elliptical orbit which would take it round in fifty years. The brightness of Sirius for a long time prevented the disturbing cause from being found out ; but at last its companion star was discovered which explained the movement satisfactorily. It is a small star with great ponderosity, but very little light. The particulars of the orbits of these binary stars can only be obtained when their distances are known ; their own proper motions are no help for this unless their parallaxes are first ascertained. Formerly the method employed for this purpose was to observe them from two different points of view situated widely apart, as the two opposite sides of the earth's orbit, distant from each other 180 millions of miles. Although this seems a very wide sweep, yet it dwindles into comparative insignificance when looking out into the depth of space, and in no case does the angle of measurement obtained amount to one second of arc. Nevertheless that is sufficient to determine many interesting facts connected with these far out heavenly bodies. The more usual method of measurement now is to observe a star suspected of proper motion in connection with one near it which has none. This method gives better results though the angle obtained is not greater than by the older way of computation.

There is reason to believe that these proper motions of the stars have produced changes in their brightness in the course of time. In Gemini, for instance, Castor and Pollux in old catalogues were lettered Alpha and Beta, but now Pollux is put first, being considerably the brighter of the two. This is significant when the fact is taken into account that it is a binary star.



KEY TO SEGMENT III.

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SEGMENT III.

STARS IN SEGMENT III.

Asterisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	Name of Constellation.	Magnitude.	R.A.			Decl.	
146	γ	Geminorum (*Alhena*). ..	2.0	6	32	N	16	28
147	ϵ	Geminorum (*Mebsuta*), ..	3.2	6	38	N	25	13
148	ξ	Geminorum, ...	3.4	6	40	N	12	59
149	α	Canis Majoris (*Sirius*), ..	1.4	6	41	S	16	35
150	κ	Canis Majoris, ...	3.9	6	46	S	32	22
151	o^1	,, ...	4.0	6	50	S	24	4
152	ι	,, ...	4.5	6	51	S	16	56
153	ϵ	,, (*Adara*), ..	1.5	6	54	S	28	50
154	51	Cephei, ...	5.3	6	56	N	87	11
155	22	Canis Majoris, ...	3.5 v.	6	57	S	27	47
156	ζ	Geminorum, ..	3.7 4.5	6	58	N	20	42
157	γ	Canis Majoris, ...	4.1	6	59	S	15	29
158	o^2	,, ...	3.0	6	59	S	23	41
159	δ	,, ...	1.9	7	4	S	26	14
160	λ	Geminorum, ...	3.6	7	12	N	16	42
161	π	Argus, ...	2.7	7	13	S	36	55
*162	δ	Geminorum (*Wasat*), ..	3.7	7	14	N	22	9
163	ι	Geminorum	4.0	7	19	N	27	59
164	η	Canis Majoris, ...	2.4	7	20	S	29	7
165	β	Canis Minoris (*Gomeisa*), ..	3.1	7	22	N	8	28
*166	α^2	Geminorum (*Castor*), ..	2.0	7	28	N	32	5
167	α	Canis Minoris (*Procyon*), ..	0.5	7	34	N	5	27
168	κ	Geminorum, ...	3.6	7	38	N	24	37
169	β	,, (*Pollux*), ..	1.1	7	39	N	28	14
170	ξ	Argus, ...	3.4	7	45	S	24	37
171	6	Cancri, ...	5.0	7	57	N	28	3
172	ζ	Argus, ...	2.5	8	0	S	39	44
173	15	,, ...	2.9	8	3	S	24	2
174	ρ	,, ...	2.9	8	3	S	24	2
175	ψ	Cancri, ...	5.8	8	4	N	25	57
176	β	,, ...	3.8	8	11	N	9	28
177	o	Ursae Majoris, ...	3.4	8	22	N	61	1
178	η	Cancri, ...	5.5	8	27	N	20	45
179	δ	Hydrae, ...	4.1	8	32	N	6	1
180	γ	Cancri, ...	4.8	8	37	N	21	47
181	δ	,, ...	4.3	8	39	N	18	29
182	ϵ	Hydrae, ...	3.6	8	41	N	6	45
183	ζ	,, ...	3.3	8	50	N	6	17
184	ι	Ursae Majoris (*Talitha*), ..	3.2	8	52	N	48	24
185	α	Cancri, ...	4.3	8	53	N	12	12
186	κ	Ursae Majoris, ...	3.7	8	57	N	47	31
187	κ	Cancri, ...	5.0	9	2	N	11	2
188	83	,, ...	6.6	9	13	N	18	5

No.	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
189	h	Ursae Majoris, ...	3.7	9	24	N	63	27
190	α	Hydrae (*Alphard*), ...	2.0	9	23	S	8	15
191	λ	Leonis, ...	4.4	9	26	N	23	23
192	θ	Ursae Majoris, ...	3.2	9	26	N	52	5
193	ψ	Argus, ...	3.7	9	27	S	40	3

DESCRIPTION OF SEGMENT IV.

Twelve hours and thirty minutes mark the point in Right Ascension when Rib No. 5 comes in, and from the centre to the circumference it passes through the Dragon at the second star from the end of the tail. Next it passes between the four right hand stars of the Plough and the three which forms the handle; and down at the equator it passes through Virgo, while 30° south the long drawn out Hydra is again met with. Ursa Major, or the Plough, is perhaps the best known figure in the sky. It has seven principal stars, though not of first magnitude, four forming a parallelogram representing the body of the plough, and three in the form of a curve at the one end, known as the handle. These seven stars have attracted attention in all ages and there is reason to believe they have maintained their present shape and form for at least two thousand years, so that they are well entitled to be called fixed stars. Besides their interest as a group they serve as a good index for finding many other objects of beauty in the northern sky. The two stars farthest away from the handle are called the pointers, because they point towards the pole star. Their names are Merak, the lower, and Dubhe, the upper. A line from these will direct the eye to Polaris, the star nearest the true pole though not actually at it. It is one of a small group called Ursa Minor, the little bear. The line of the pointers also passes the first star of the dragon's tail, which being found, the whole tortuous body of Draco may be traced out to the left. The names of the two stars opposite to the pointers are Megrez the upper and Phecda the lower. In the handle the first from the left is Benetnasch, Mizar in the middle, and Alioth at the other side. Three pairs of stars equidistant, and lying in the line of a great curve about 20° from the

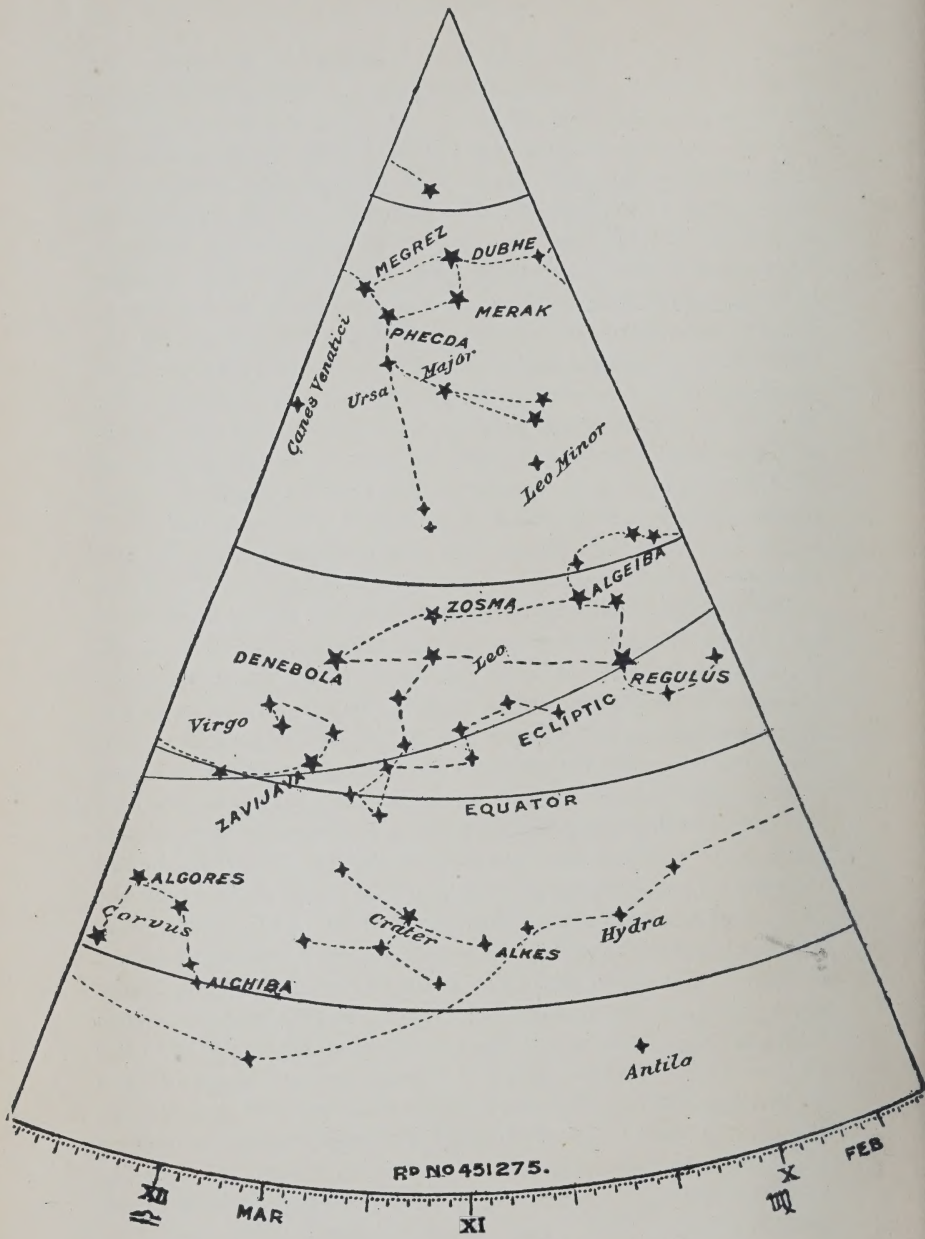
lower pointer, are the paws of the bear. Leo, the lion, is one of the twelve signs. It has an interest beyond the others on account of its definiteness of form, though it has no resemblance to a lion. It is situated directly under the Plough, and its most characteristic outline is " the sickle of the lion," a group of stars shaped like a reaping hook with its edge towards the right and the bright star Regulus for the handle. The remainder of the constellation is towards the left, ending with Denebola 30° away, which is the tail of the lion. The portion of Hydra in this segment is important because of the two small groups of stars on its back, Crater, the cup, and Corvus, the crow, the latter being close to the edge of the segment. These form the best identifying features of Hydra, which is a very long undulating succession of stars, appearing in three segments of the Umbrella, and measuring a whole quadrant of degrees from beginning to end.

The well-known November meteors radiate from " the sickle of the lion," and consequently are called " the Leonids." They came into prominent public notice in the year 1866, having been predicted to occur from a comparison of old astronomical data, which showed that at intervals of 33 years such showers had happened before at that particular time of the year. This fact of periodical occurrence having been established led to the investigation of the cause, which was ultimately attributed to the earth having passed through the tail of a comet. Tempel's comet had just passed that way a year before, and the tail was still lingering behind. It is well known that comets are not solid bodies, but are made up of matter which is not dense enough to be opaque. They do not occult the stars they pass over. These stars can be distinctly seen through them as a lady's face through her veil, and meteoric particles would form a screen of this kind. A solid substantial body like the earth would have no difficulty in penetrating through such ephemeral material spread out in long straggling procession. The shield of defence against serious danger from the shower is of course the density and depth of the atmosphere. Before these meteoric stones or pebbles or dust of various sorts and sizes can reach the ground they are burnt up by the friction of passing through the atmosphere, and are wafted to the earth in the harmless form of ashes. While the process is going on it is a very alarming

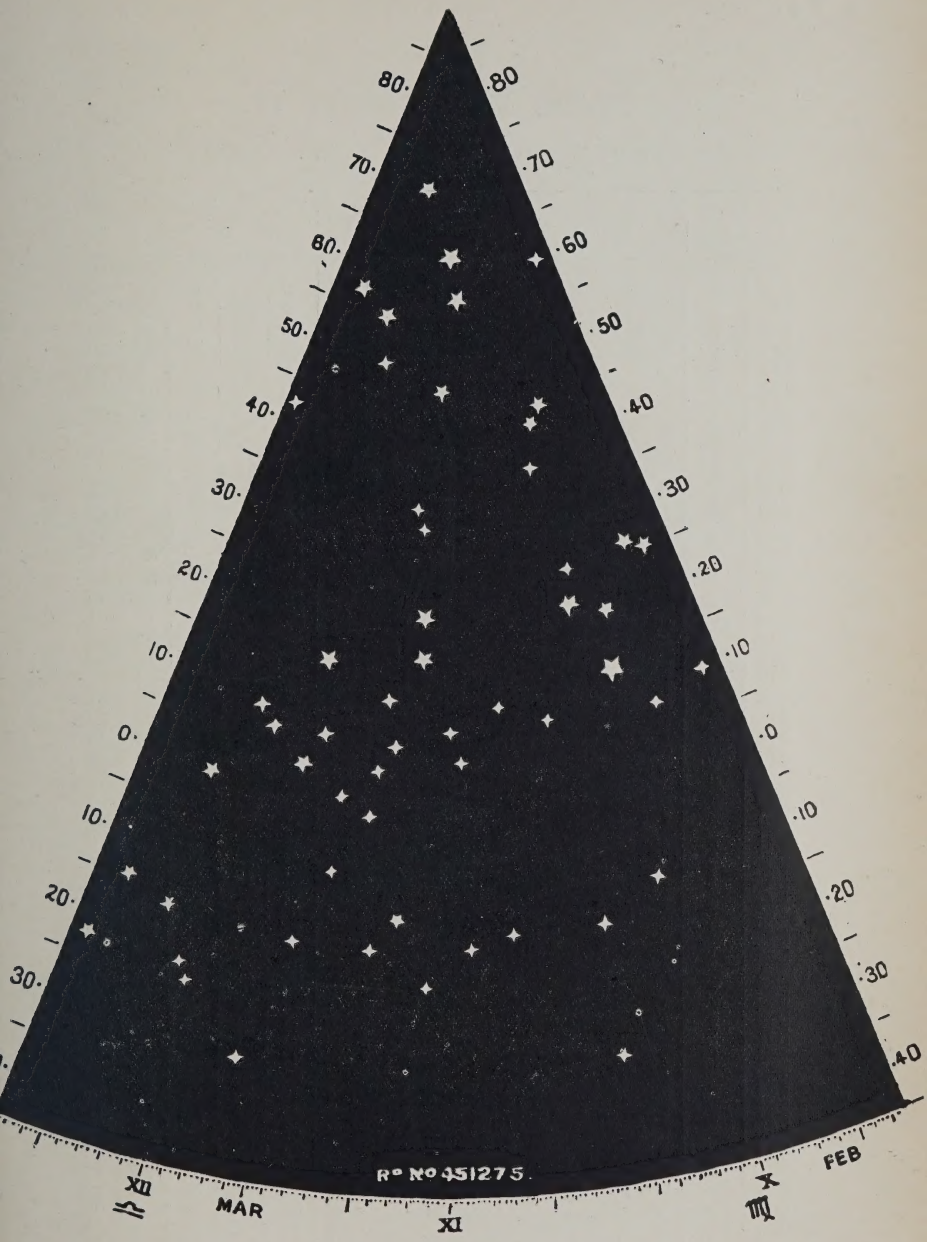
sight, as many as 100,000 an hour bursting into streams of fire in simultaneous rush and keeping up a continuous bombardment for several hours.

There are four periodic groups of meteor showers well established by frequent occurrence, and they are all connected with comets whose orbits are known: The Leonids and Andromedes in November, the Perseids in August, and the Lyrids in April. They do not all return in the same force every year, but vary in density according as they are scattered along their orbits as the Perseids, or more concentrated like the Leonids. In the latter case the larger showers will only occur at intervals of years, according as the earth in crossing the meteoric orbit happens to pass through a dense shoal. After the Leonids the Andromedes are next in importance because of their connection with Biela's comet, discovered in 1826 by an Austrian of that name. This comet returned in periods of about six and a half years, up to the year 1846, when it was disrupted, torn in two by some unknown influence. The two portions returned in due course in 1852 further apart from each other. They were never seen again as comets, but probably as meteors. In 1872, as the earth crossed the old track of this comet, there was a wonderful shower of meteors, and again in 1885 the same thing occurred. These meteors and the comet are evidently one and the same, though seen in a different point of view and in altered circumstances.

There are larger meteoric stones that are not pulverised by the friction of passing through the air, but make the passage successfully and fall upon the earth. They are only diminished in size by the scorching process, and lessened in velocity by the density of the atmosphere slowing down from over forty miles a second to less than ten. These have been known to fall in something like a shower, as in Normandy and Bohemia in the early years of last century. It is no doubt a meteoric stone which is referred to in Acts xix. 35, out of which an image of the goddess Diana was sculptured and afterwards worshipped by the Ephesians. History relates that a stone of this sort fell in Phrygia B.C. 204. It was regarded with superstitious veneration and carried to Rome as a sacred deposit, to ensure the welfare of the state. There is a large collection of meteoric stones in the British Museum.



KEY TO SEGMENT IV.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SEGMENT IV.

STARS IN SEGMENT IV.

Astesisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	Name of Constellation.	Magnitude.	R.A.			Decl.	
194	o	Leonis, ...	3.8	9	36	N	10	18
195	ϵ	,, ...	3.1	9	40	N	24	11
196	υ	Ursae Majoris, ...	4.0	9	44	N	59	28
197	μ	Leonis, ...	4.1	9	47	N	26	26
198	π	,, ...	5.0	9	55	N	8	29
199	η	,, ...	3.6	10	2	N	17	12
200	α	,, (*Regulus*), ...	1.4	10	3	N	12	25
201	λ	Hydrae, ...	3.9	10	6	S	11	53
202	ζ	Leonis, ...	3.6	10	11	N	23	53
203	λ	Ursae Majoris, ...	3.6	10	11	N	43	22
*204	γ^1	Leonis, ...	2.5	10	14	N	20	18
205	μ	Ursae Majoris, ...	3.1	10	16	N	41	57
206	μ	Hydrae, ...	4.1	10	21	S	16	21
207	β	Leonis Minoris, ...	4.5	10	22	N	37	11
208	α	Antilae, ...	4.5	10	22	S	30	35
209	ρ	Leonis, ...	4.0	10	27	N	9	46
210	l	,, ...	5.3	10	44	N	11	1
211	ν	Hydrae, ...	3.3	10	44	S	15	42
212	α	Crateris (*Alkes*), ...	4.1	10	55	S	17	48
213	d	Leonis, ...	5.0	10	55	N	4	6
214	β	Ursae Majoris (*Merak*), ..	2.6	10	56	N	56	52
215	α	Ursae Majoris (*Dubhe*), ..	2.0	10	57	N	62	14
216	χ	Leonis, ...	4.7	11	0	N	7	50
217	ψ	Ursae Majoris, ...	3.1	11	4	N	44	59
218	β	Crateris, ...	4.4	11	7	S	22	18
219	δ	Leonis (*Zosma*), ...	2.8	11	9	N	21	1
220	θ	Leonis, ...	3.5	11	9	N	15	55
*221	ξ	Ursae Majoris, ...	3.8	11	12	N	32	9
222	ν	,, ...	3.8	11	13	N	33	36
223	δ	Crateris, ...	3.9	11	14	S	14	16
224	σ	Leonis, ...	4.1	11	15	N	6	32
*225	ι	,, ...	5.1	11	19	N	11	28
226	γ	Crateris, ...	4.2	11	20	S	17	9
227	τ	Leonis, ...	5.1	11	23	N	3	22
228	ϵ	,, ...	5.0	11	25	S	2	28
229	λ	Draconis, ...	4.1	11	25	N	69	50
230	θ	Crateris, ...	4.7	11	31	S	9	16
231	ζ	,, ...	4.9	11	39	S	17	48
232	υ	Leonis, ...	4.5	11	32	S		18
233	ν	Virginis, ...	4.2	11	41	N	7	3
234	χ	Ursae Majoris, ...	3.9	11	41	N	48	17
235	β	Leonis (*Denebola*), ...	2.2	11	44	N	15	5
236	β	Virginis (*Zavijavi*), ...	3.7	11	45	N	2	17
237	β	Hydrae, ...	4.0	11	48	S	33	22
238	γ	Ursae Majoris (*Phecda*), ..	2.6	11	48	N	54	12
239	π	Virginis, ...	4.4	11	56	N	7	7
240	o	,, ...	4.3	12	0	N	9	14

No	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
241	α	Corvi (*Alchiba*), ...	4.3	12	3	S	24	11
242	ϵ	Corvi, ...	3.1	12	5	S	22	5
243	δ	Ursae Majoris (*Megrez*), ..	3.4	12	10	N	57	32
244	γ	Corvi, ...	2.8	12	11	S	17	1
245	η	Virginis, ...	4.1	12	15	S		8
246	δ	Corvi (*Algores*), ...	3.1	12	25	S	15	59
247	β	Corvi, ...	2.8	12	29	S	22	52
248	β	Canum Venat., ...	4.3	12	29	N	41	51
249	κ	Draconis, ...	3.8	12	29	N	70	17

DESCRIPTION OF SEGMENT V.

Rib No. 6 has its position between the hours XV. and XVI. From the pole star it runs through the body of the little bear, thereby preventing its outline from being seen. Farther down it crosses the dragon, and at 30° north it completely shuts out the gem of the Northern Crown Alphecca, and rather spoils this fine group. Above the equator it meets the head of the Serpent, and below the equator it divides Libra in two. Ursa Minor is only important because of the pole star, the principal star in the group, and other two attendants called the "guards of the pole." Draco, the dragon, can be traced by taking the last star first, which is nearly in the line of the pointers. It has a curving downward course, then it turns upward making three complete twists of its body—but these are rather obscure. The head then droops in a straight line towards Hercules, the two eyes being plainly visible, Alwaid and Etanin. Boötes, the herdsman, is well marked by Arcturus of first magnitude, towards which the tail of the great bear points. Virgo is known by the star of first magnitude Spica, nearly in line with Vega and Arcturus, but low in the horizon.

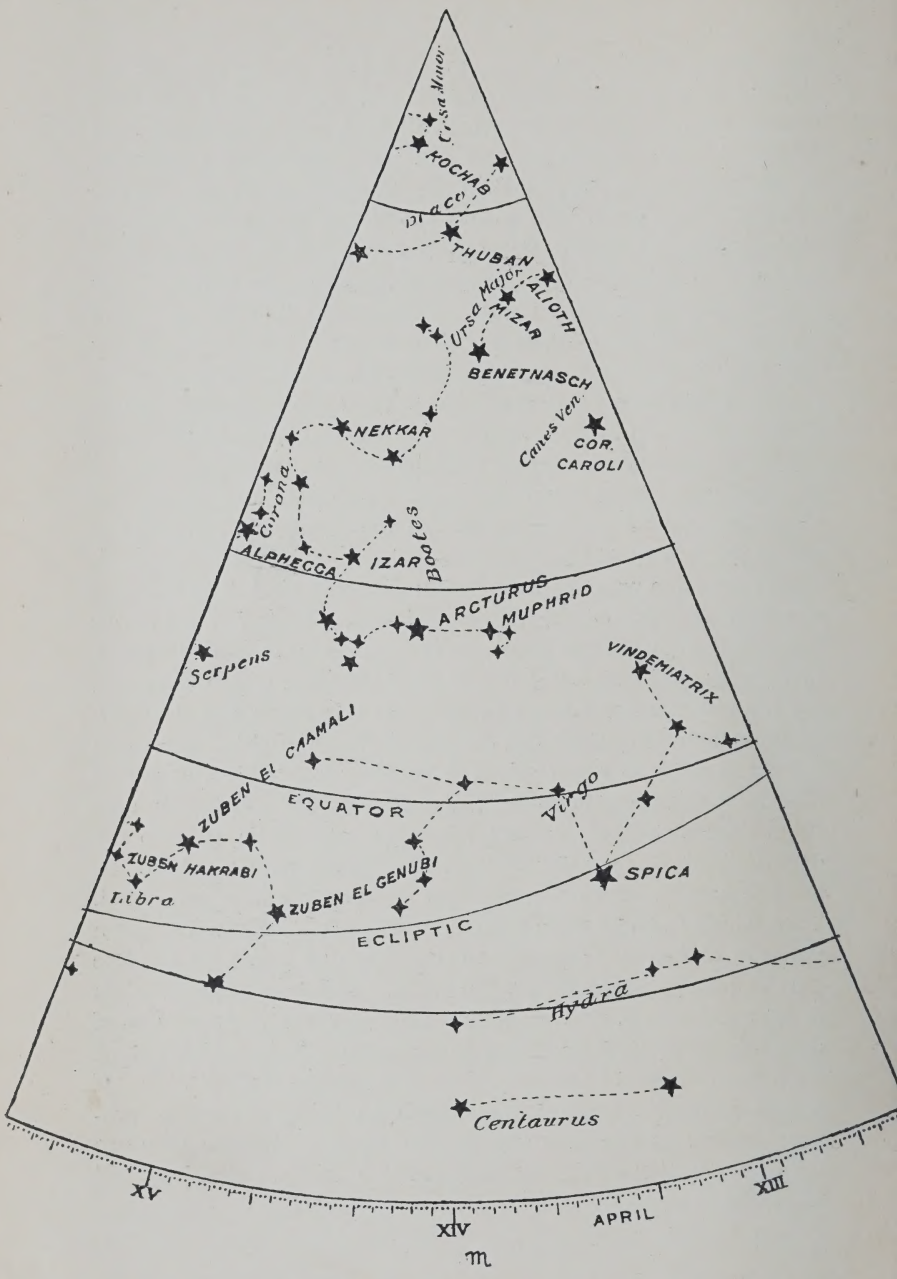
The star Delta in the Scales is one of the remarkable variable stars of which Algol in Perseus is the type. It is situated near Zuben el Chamali, one of the three Zubens of this constellation which owe their designation to the Arabs in their palmy days. It is not a bright star, but only of fifth magnitude at its best; its regular intermediate changes are very marked, diminishing

a magnitude and a half every two days eight hours nearly. Its period, like that of Algol, is very accurately known even to a fraction of a second, because of the spectroscopic observations which have been made. It has been demonstrated that the diminution of its brightness is due to a partial eclipse of the brighter star by a darker one revolving round it. The spectroscope has been the means of enlarging the knowledge of heavenly bodies quite as much as the more recently applied art of photography, though in a different way. It is an adaptation of the telescope by which the light coming from a star can be analyzed so as to show the principal materials of its composition. A prism or a series of prisms is adjusted in the instrument so as to intercept the rays and show the spectrum. The solar spectrum is well known to consist of the seven colours—red, orange, yellow, green, blue, indigo, and violet. The light from other bodies shows the predominance of one or other of the chemical elements by imposing extra bands, and so varying the spectrum in a definite and characteristic way. The spectroscope has also the wonderful power of showing the movements of stars in the line of sight if they are receding or approaching, and the rate of such movements. The rapid motion in either direction causes the characteristic bands to shift in the spectrum or to incline out of the perpendicular. The explanation of this is illustrated by the way in which the sound wave of music reaches the ear. If the sound is approaching at a rapid rate, as the whistle of a locomotive engine, the waves of sound will be pushed together and become exaggerated in accent and raised to a higher pitch. The contrary effect is produced if the sound is receding ; the waves of sound passing through the air will be flattened out and the note in consequence lowered in pitch. The light waves are affected in the very same way ; the excessively rapid rates of movement of these distant stars so affect the lines of colour in the spectroscope that the differences can be measured and tabulated.

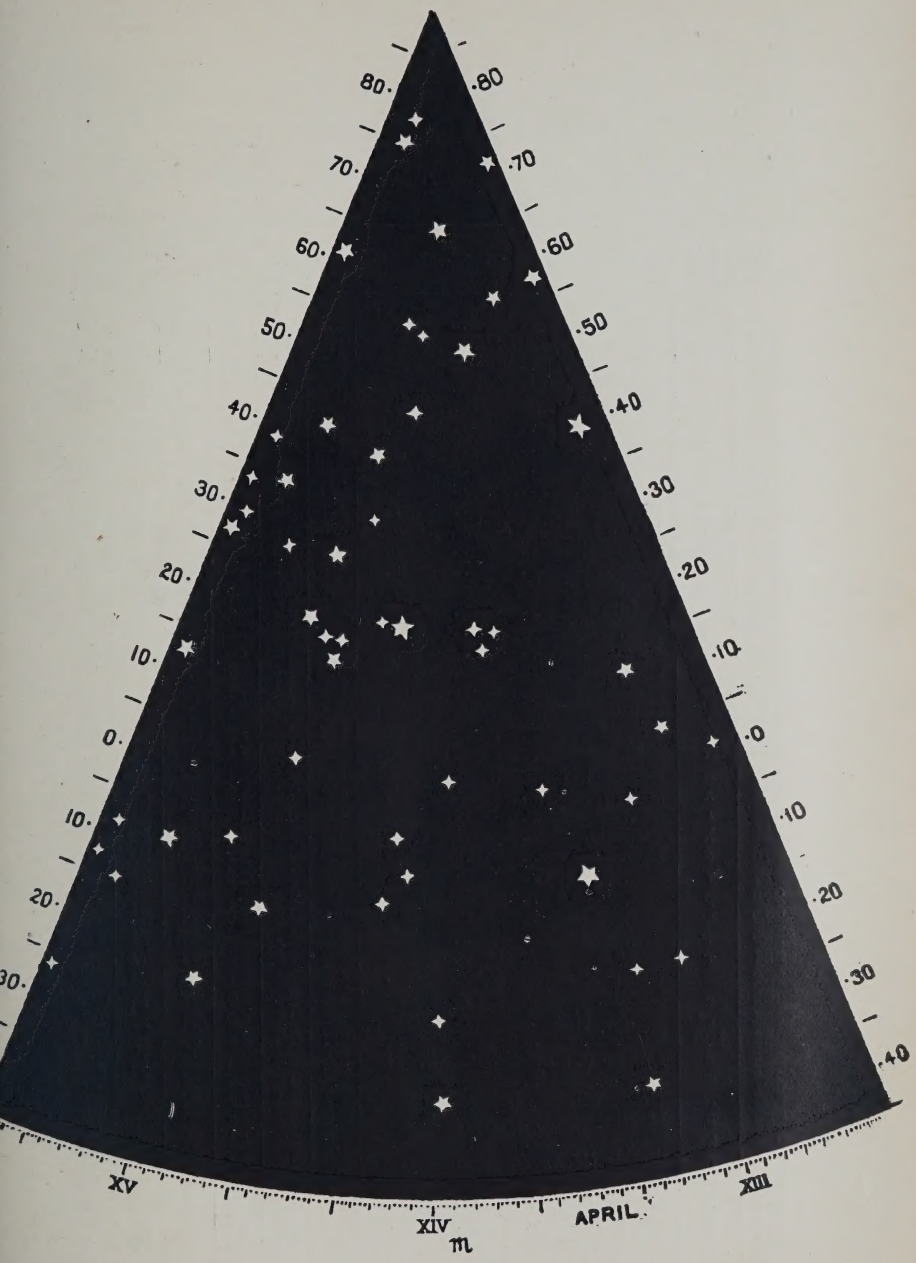
Another useful and interesting purpose to which the spectroscope has been put, is to show the prominences of the Sun although there be no eclipse. It is not such a brilliant display as is afforded when the moon passes over the sun's disc, but only a reproduction of it on a small scale, yet a real sample of the genuine article.

The darting tongues of flame are seen just as the prominences show in an eclipse. A piece of glass very closely ruled with lines (10,000 to the inch) is used instead of a prism, and the light admitted only through a small slit. The sun's limb is brought to the edge of this slit and then the prominences are seen on the small portion of the disk within the field of the instrument. A more systematic observation can be carried on in this way than by the snatch glances on the rare occasions of an eclipse. The prominences have been roughly classified as "quiescent" and "eruptive," or what might be called ordinary and extraordinary kinds. The quiescent are those which are constantly present, as if this were the normal condition. They are enormous clouds of fire, reaching a height of many thousands of miles, and occupying correspondingly large areas of surface. As they rise, developments take place into rounded contours and spreading expansions, seeking freedom in the upper regions beyond the rim of the sun's mass.

The eruptive prominences show a different kind of action and are very erratic, as the name indicates. They are evidently connected with the sun spots, as they are always more frequent when near that particular region of the surface where the spots are found—about the sun's equator. Their shape and size vary very much and very quickly, darting aloft to a height of a hundred thousand miles in a few minutes, showing a terrible velocity of motion. The constitution of the sun clearly shows that it contains enormous heat, and at the same time radiates it to the utmost limits of the solar system. It does so with a prodigality truly amazing, when the amount is even roughly estimated. That which radiates from a portion of the sun's circumference a yard in diameter, is nearly 50,000 times as great as the like patch of surface receives on the earth. The temperature, when it leaves the sun, is very high; though there is no means of ascertaining it with anything like accuracy it is estimated at from ten thousand to twenty thousand degrees Fahrenheit. If a lens could be made large enough to bring the earth proportionately as near the sun as the moon's distance (239,000 miles) from the earth, nothing could withstand the heat, all would be dissipated in vapour.



KEY TO SEGMENT V.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SEGMENT V.

STARS IN SEGMENT V.

Asterisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	Name of Constellation.	Magnitude.	R.A.			Decl.	
*250	γ^1	Virginis, ...	3.5	12	36	S		56
251	ϵ	Ursae Majoris (*Alioth*), ...	1.8	12	49	N	56	27
252	δ	Virginis, ...	3.7	12	50	N	3	53
*253	α	Canum Venat. (*Cor Caroli*),	3.0	12	51	N	38	48
254	ϵ	Virginis (*Vindematrix*), ..	3.0	12	57	N	11	27
255	ψ	Hydrae, ...	5.1	13	3	S	22	37
*256	θ	Virginis, ...	4.4	13	5	S	5	2
257	γ	Hydrae, ...	3.4	13	13	S	22	40
258	ι	Centauri, ...	3.0	13	15	S	36	13
259	α	Virginis (*Spica*), ...	1.2	13	20	S	10	40
*260	ζ^1	Ursae Majoris (*Mizar, Alcor*),	2.6	13	20	N	55	24
261	ζ	Virginis, ...	3.5	13	29	S		7
262	τ	Boötis, ...	4.5	13	42	N	17	54
263	η	Ursae Majoris (*Benetnasch*),	2.0	13	43	N	49	46
264	υ	Boötis, ...	4.0	13	44	N	16	16
265	η	,, (*Muphrid*), ...	2.9	13	50	N	18	51
266	τ	Virginis, ...	4.4	13	56	N	1	59
267	θ	Centauri, ...	1.7	14	1	S	35	54
268	π	Hydrae, ...	3.5	14	1	S	26	13
269	α	Draconis (*Thuban*), ...	3.6	14	1	N	64	48
270	κ	Virginis, ...	4.3	14	7	S	9	50
271	ι	,, ...	4.2	14	11	S	5	33
272	α	Boötis (*Arcturus*), ...	1.0	14	11	N	19	39
273	λ	Boötis, ...	4.3	14	12	N	46	38
*274	ι	,, ...	4.8	14	12	N	51	48
275	λ	Virginis, ...	4.6	14	13	S	12	57
276	θ	Boötis, ...	4.2	14	22	N	52	16
277	f	,, ...	5.4	14	22	N	19	38
278	ρ	,, ...	3.6	14	27	N	30	46
279	γ	,, ...	3.1	14	28	N	38	42
*280	π	,, ...	4.6	14	36	N	16	49
281	ζ	,, ...	3.8	14	36	N	14	7
282	5	Ursae Minoris, ...	4.3	14	27	N	76	7
283	o	Boötis, ...	4.8	14	40	N	17	22
*284	ϵ^2	,, (*Izar*), ...	2.6	14	40	N	27	27
285	109	Virginis, ...	3.7	14	41	N	2	16
286	α	Librae (*Zuben-el-Genubi*), ..	3.0	14	45	S	15	39
*287	ξ	Boötis, ...	4.6	14	47	N	19	29
288	β	Ursae Minoris (*Kochab*), ..	2.1	14	50	N	74	31
289	δ	Librae, ...	4.9	14	56	S	8	8
290	20	,, ...	3.2	14	58	S	24	54
291	β	Boötis (*Nekker*), ...	3.6	14	58	N	40	45
292	ψ	Boötis, ...	4.5	15	0	N	27	18
293	β	Librae (*Zuben el Chamali*),	2.7	15	11	S	9	2
294	δ	Boötis, ...	3.6	15	11	N	33	39
295	γ	Ursae Minoris, ...	3.2	15	20	N	72	9

No.	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
*296	μ	Boötis, ...	4.4	15	21	N	37	42
297	ρ	Librae, ...	4.0	15	22	S	16	24
298	ι	Draconis, ...	3.4	15	22	N	59	17
299	β	Coronae Borealis, ...	3.8	15	24	N	29	25
300	θ	,, ,, ...	4.3	15	29	N	31	40
301	α	,, ,, (*Alphecca*),	2.4	15	30	N	27	1
*302	δ	Serpentis, ...	4.0	15	30	N	10	51
303	γ	Librae (*Zuben Hakrabi*), ..	4.0	15	30	S	14	28

DESCRIPTION OF SEGMENT VI.

Three hours more Right Ascension reaches the point marked eighteen hours thirty minutes, where Rib No. 7 terminates. It passes near Vega, the chief star in the Lyre, and crosses the serpent at the equator and Sagittarius at the ecliptic. Hercules of ancient mythological renown, is represented in the sky by a very large constellation, none of the stars, however, being greater than the third magnitude. The principal configuration is a quadrilateral, becoming narrower at one end. It is on a line from Vega to Corona. Corona Borealis, the Northern Crown, is perhaps the constellation which most of all justifies its name, and requires no effort of the imagination to improve it as nearly all the others do. It is a semi-circle of stars, five in number and very symmetrical in form, with a brighter one in the middle called the "gem of the crown." There is no mistaking it when once seen. In the Umbrella Star Map it is rather out of form because of the joining at the rib.

Ophiucus, the serpent holder, is just above the equator, impinging upon the Milky Way in this region of the sky. The serpent itself is supposed to be writhing in the hands of Ophiucus, with its head just under the Northern Crown, and its tail extending well on towards Altair in Aquila. Scorpio, the scorpion, one of the signs of the Zodiac, is low down in the sky. Its principal star Antares is of the first magnitude and of a fiery red colour like the planet Mars, whence it derives its name as rivalling it in lustre, Ares being the Greek name of Mars. Sagittarius, the

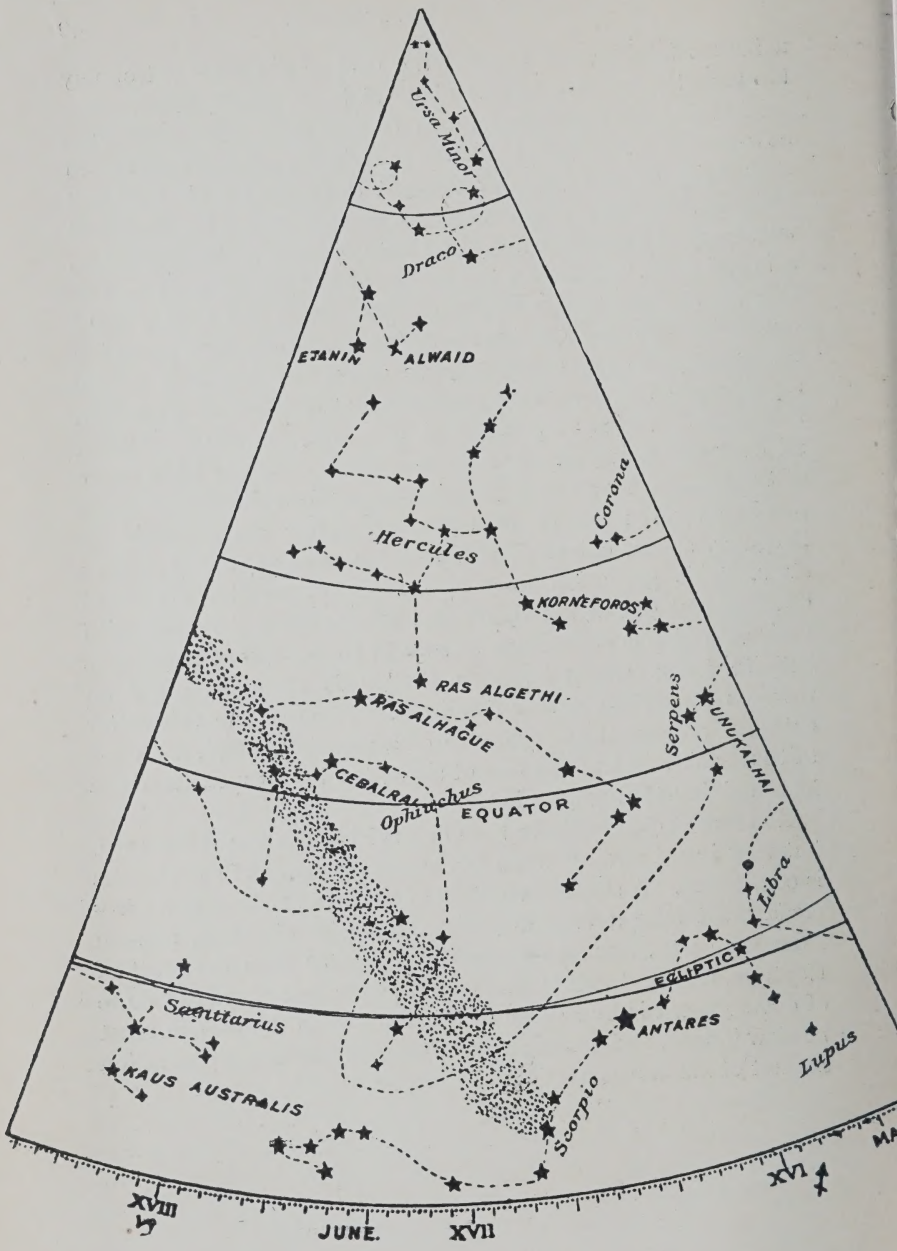
archer of the Zodiac, is situated where the lower solstitial point in the ecliptic is at present. It crosses through the Milky Way at the ending of the branch towards the east. Scorpio is at the end of the western branch.

The annular (ring shaped) nebula in Lyra is situated in right ascension 18 ho. 48 m. with 32° 59′ of declination. This is a very symmetrical circle measuring about three minutes of arc across. It is not a very large nebula, but its structure is very well defined, the interior of the ring is dark and there is a broad margin of bright light all round the circumference about thirty seconds of arc in breadth. This gives it a very self-contained appearance, and favours the conjecture that it is in process of development by rapid rotation. It is only since photography began to be employed in astronomy that reliable pictures of the true forms of nebulae have been obtained. Telescopes, even of the highest power, are not equal to the task of showing these masses as they really are. Formerly certain markings were discerned in some of them, which for want of a more accurate description were called "lanes." These were seen as dark dividing spaces between different layers of luminous matter. The photographic plate, however, with long exposure reveals the outlines of such forms to be continuous circles, ovals or spirals, the "lanes" coming out as distinct divisions like the rings of Saturn. These nebulae are thus proved to be homogeneous entities, suggesting the theory that they are systems of suns and planets in process of formation. The great nebula in Andromeda is one of those which have been brought into shape and form in this way. Formerly it and many others appeared as a picture thrown on the screen would do when out of focus, a dull, blurred, undefined mass with dark patches running through it. The impressions now obtained by photography are quite as different from this as when such a dull unfocussed picture is suddenly drawn into true focus bringing out its form in distinct outline. The spectroscope reveals the fact that the nebulae have proper motions of their own in space, and as a rule much more rapid than the more solid stars, some of them reaching the enormous rate of a hundred miles a second in the line of sight. It may yet be determined that they have their orbital motion in lateral directions as well, but these

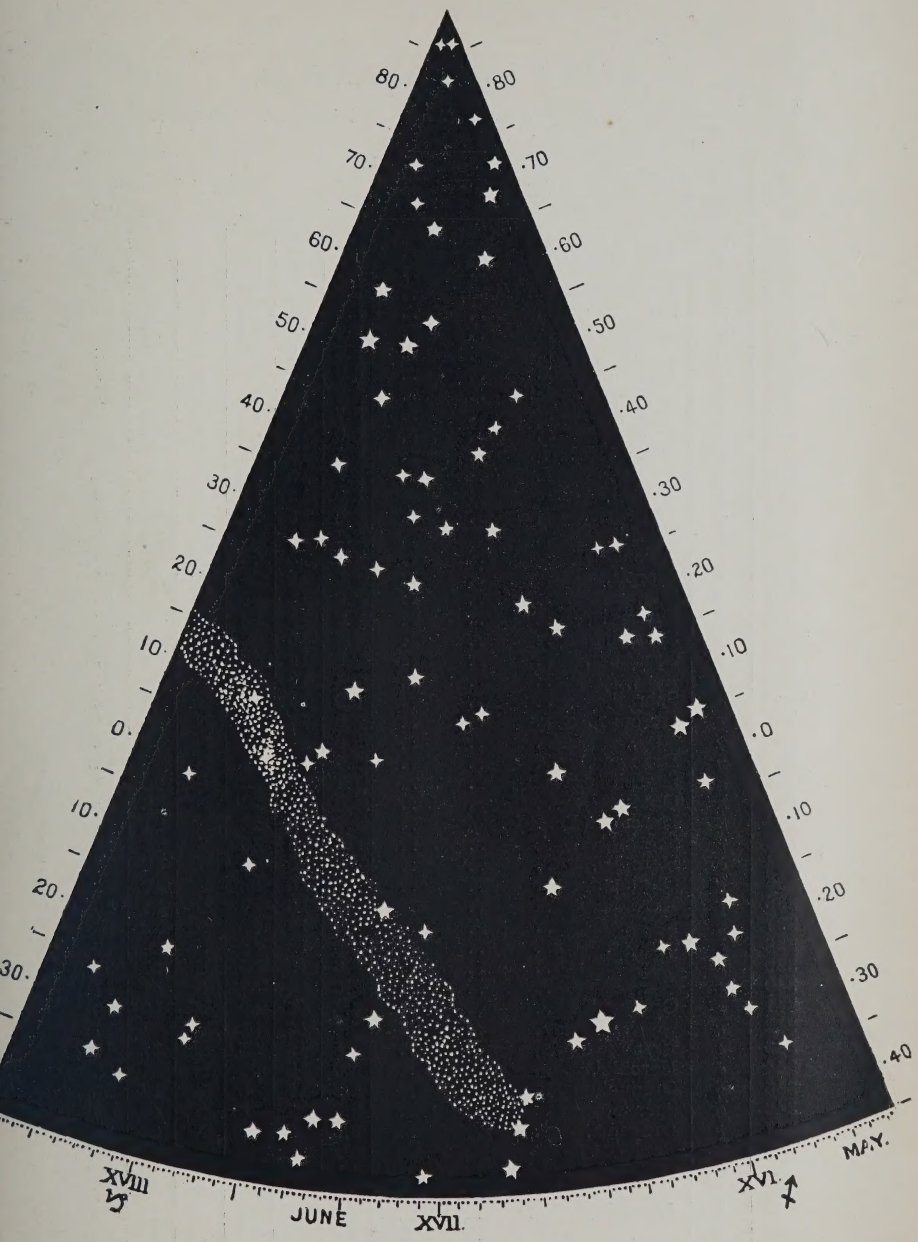
nebulous bodies have entered the field of practical astronomy too recently for data of this kind yet to be accumulated.

Photography has added much to this branch of astronomy, as to almost every other branch of the science. It has been shown that many objects formerly thought to be of this kind are not really so, but are clusters of stars so closely packed together that telescopes of highest power could not detect anything more than a bright haze. Although the number has been reduced on this side by the keener eye of the camera, yet it has been greatly multiplied on the other side by the photographic plate revealing many other true nebulae hitherto unknown. There is hardly a portion of the sky where nebulous matter is not to be found, although it varies very much in quantity, density and form, all over the universe. A reliable classification has been made of the nebulae by a closer examination of their differences made possible by the art of photography. They are classified as irregular, spiral, elliptical, and annular nebulae, and nebulous stars. This gradation may also mark progressive stages of development out of the thinly and widely diffused masses with their voluminous extensions, as seen in Orion, through the more definite forms where rotatory motion is certainly going on towards the nebulous star condition. Those put in this latter category present the appearance of a receding comet, with the tail fore-shortened in the line of sight, the bright nucleus of the head shining through behind.

No marked changes have been observed to confirm this theory, but that is not strange when the enormous range of such bodies is considered. A single revolution of the great Nebula in Andromeda must take a very long time, since its diameter, as seen from the earth, must be many times greater than the orbit of Neptune, and that planet goes round in 164 years. If the cause of development is by motion of this kind, then the growth must be slow indeed, and all the observations possible in one generation are not of much account in estimating it.



KEY TO SEGMENT VI.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SEGMENT VI.

STARS IN SEGMENT VI.

Asterisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	Name of Constellation.	Magnitude.	R.A.			Decl.	
304	39	Librae, ...	3.9	15	31	S	27	49
305	37	,, ...	4.9	15	31	S	9	44
306	α	Serpentis (*Unukalhai*), ..	2.7	15	39	N	6	42
307	β	Serpentis, ...	3.8	15	41	N	15	42
308	κ	,, ...	4.2	15	44	N	18	25
309	μ	,, ...	3.5	15	44	S	3	8
310	χ	Lupi, ...	4.0	15	44	S	33	17
311	δ	Coronae Borealis, ...	4.6	15	45	N	26	21
312	ϵ	Serpentis, ...	3.7	15	46	N	4	45
313	λ	Librae, ...	5.0	15	47	S	19	52
314	ζ	Ursae Minoris, ...	4.5	15	47	N	78	4
315	θ	Librae, ...	4.3	15	48	S	16	27
316	ρ	Scorpii, ...	4.0	15	50	S	28	56
317	γ	Serpentis, ...	4.0	15	52	N	15	57
318	π	Scorpii, ...	3.1	15	53	S	25	50
319	ϵ	Coronae Borealis, ...	4.1	15	53	N	27	8
320	δ	Scorpii, ...	2.5	15	54	S	22	21
*321	β^1	,, ...	3.0	15	59	S	19	32
322	θ	Draconis, ...	4.2	15	59	N	58	48
*323	ν	Scorpii, ...	4.2	16	6	S	19	13
324	δ	Ophiuchi, ...	2.8	16	9	S	3	27
325	ϵ	,, ...	3.4	16	13	S	4	27
*326	σ	Scorpii, ...	3.0	16	15	S	25	22
327	τ	Herculis, ...	3.9	16	16	N	46	31
328	γ	,, ...	3.8	16	17	N	19	22
329	η	Draconis, ...	2.8	16	22	N	61	43
*330	α	Scorpii (*Antares*), ...	1.1	16	23	S	26	13
331	λ	Ophiuchi, ...	4.0	16	26	N	2	11
332	β	Herculis (*Korneforos*), ..	2.8	16	26	N	21	41
333	τ	Scorpii, ...	2.9	16	30	S	28	1
334	σ	Herculis, ...	4.2	16	31	N	42	37
335	ζ	Ohpiuchi, ...	2.8	16	32	S	10	22
336	ζ	Herculis, ...	3.1	16	37	N	31	46
337	η	,, ...	3.7	16	39	N	39	6
338	ϵ	Scorpii, ...	2.2	16	44	S	34	7
339	μ^1	,, ...	3.6	16	45	S	37	32
340	ζ	,, ...	3.6	16	47	S	42	11
341	ι	Ophiuchi, ...	4.4	16	49	N	10	19
342	κ	,, ...	3.4	16	53	N	9	31
343	ϵ	Ursae Minoris, ...	4.5	16	55	N	82	11
344	ϵ	Herculis, ...	4.0	16	56	N	31	3
345	η	Ophiuchi, ...	2.6	17	5	S	15	36
346	η	Scorpii, ...	3.6	17	5	S	43	7
347	ζ	Draconis, ...	3.3 v.	17	8	N	65	49
*348	α^1	Herculis (*Ras Algethi*), ..	3.1 3.9	17	10	N	14	29
*349	δ	Herculis, ...	3.3	17	11	N	24	56
350	π	,, ...	3.4	17	11	N	36	54

No.	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
351	u	Herculis, ...	4.9	17	13	N	33	12
352	ν	Serpentis, ...	4.4	17	15	S	12	44
*353	μ	Draconis, ...	3.2	17	3	N	54	37
354	θ	Ophiuchi, ...	3.4	17	16	S	24	54
*355	ρ	Herculis, ...	4.1	17	20	N	37	14
356	d	Ophiuchi, ...	5.3	17	21	S	4	13
357	σ	,, ...	4.4	17	21	N	29	46
358	υ	Scorpii, ...	2.8	17	24	S	37	13
359	λ	,, ...	1.7	17	27	S	37	2
360	λ	Herculis, ...	4.3	17	27	N	26	10
361	β	Draconis (*Alwaid*), ...	3.0	17	28	N	52	21
362	θ	Scorpii, ...	2.1	17	30	S	42	56
363	α	Ophiuchi (*Ras Alhague*), ..	2.2	17	30	N	12	37
364	κ	Scorpii, ...	2.6	17	36	S	38	58
365	ι	Herculis, ...	3.9	17	36	N	46	4
366	ω	Draconis, ...	4.9	17	37	N	68	47
367	β	Ophiuchi (*Cebalrai*), ..	2.9	17	38	N	4	36
368	ι^1	Scorpii, ...	3.3	17	41	S	40	5
*369	ψ	Draconis, ...	4.5	17	43	N	72	11
370	μ	Herculis, ...	3.5	17	42	N	27	46
371	γ	Ophuchi, ...	3.8	17	43	N	2	44
372	ξ	Draconis, ...	3.9	17	51	N	56	52
373	ν	Ophiuchi, ...	3.5	17	53	S	9	45
374	θ	Herculis, ...	4.0	17	53	N	37	15
375	ξ	,, ...	3.9	17	54	N	29	14
376	γ	Draconis (*Etanin*), ...	2.4	17	54	N	51	29
377	67	Ophiuchi, ...	4.0	17	56	N	2	55
378	γ^2	Sagittarii, ...	3.0	17	59	S	30	25
379	γ^1	,, ...	4.9	17	59	S	29	35
380	72	Ophiuchi, ...	3.9	18	2	N	9	32
381	δ^2	Ursae Minoris, ...	4.3	18	2	N	86	36
382	o	Herculis, ...	4.0	18	3	N	28	44
383	μ	Sagittarii, ...	4.1	18	8	S	21	4
384	η	,, ...	3.0	18	11	S	36	47
385	δ	,, ...	2.8	18	14	S	29	51
386	η	Serpentis, ...	3.4	18	16	S	2	55
387	ϵ	Sagittarii, ...	2.1	18	17	S	34	25
388	λ	,, ...	3.1	18	22	S	25	28
389	δ^1	Ursae Minoris, ...	4.3	18	33	N	86	37

EXERCISE.

Construct a catalogue of the stars in the constellation Hercules, thus :—

Put one end of the moveable scale to the pole, and pass the graduated edge through each star in succession. Note the degrees of declination north or south, and the time of Right Ascension at the hour circle ; set these down in columns, using the Greek letter for the star's name.

DESCRIPTION OF SEGMENT VII.

The next rib, which is No. 8, intersects the time circle at twenty-one hours thirty minutes. It passes the star Alphirk in Cepheus at 70° north, and does not again pass through any constellation until it reaches the ecliptic, when the Zodiacal sign of Aquarius, the water-bearer, is reached. In the segment thus enclosed there are several constellations. Cepheus has a lozenge shaped group of four stars, which resembles the Southern Cross in form. Cygnus, the swan, has a large cross not quite symmetrical, but a good enough identifying mark. The bright star Arided in the dividing of the Milky Way represents the head leaning a little to one side, and about 25° lower down Albireo marks the foot. The arms are formed by two stars of equal magnitude and equidistant from the centre star where the intersection lies. The star 61 Cygnus, which till recently was considered our nearest neighbour, but is now put third in order, is 10° from Arided on the east side of the Milky Way. It is 8 light-years distant. Aquila, the eagle, has a conspicuous group of three stars very similar to Orion's belt, lying across the Milky Way. Altair of first magnitude is in the middle, with Tarazed on the upper side and Alshain on the lower : the three measure five degrees across.

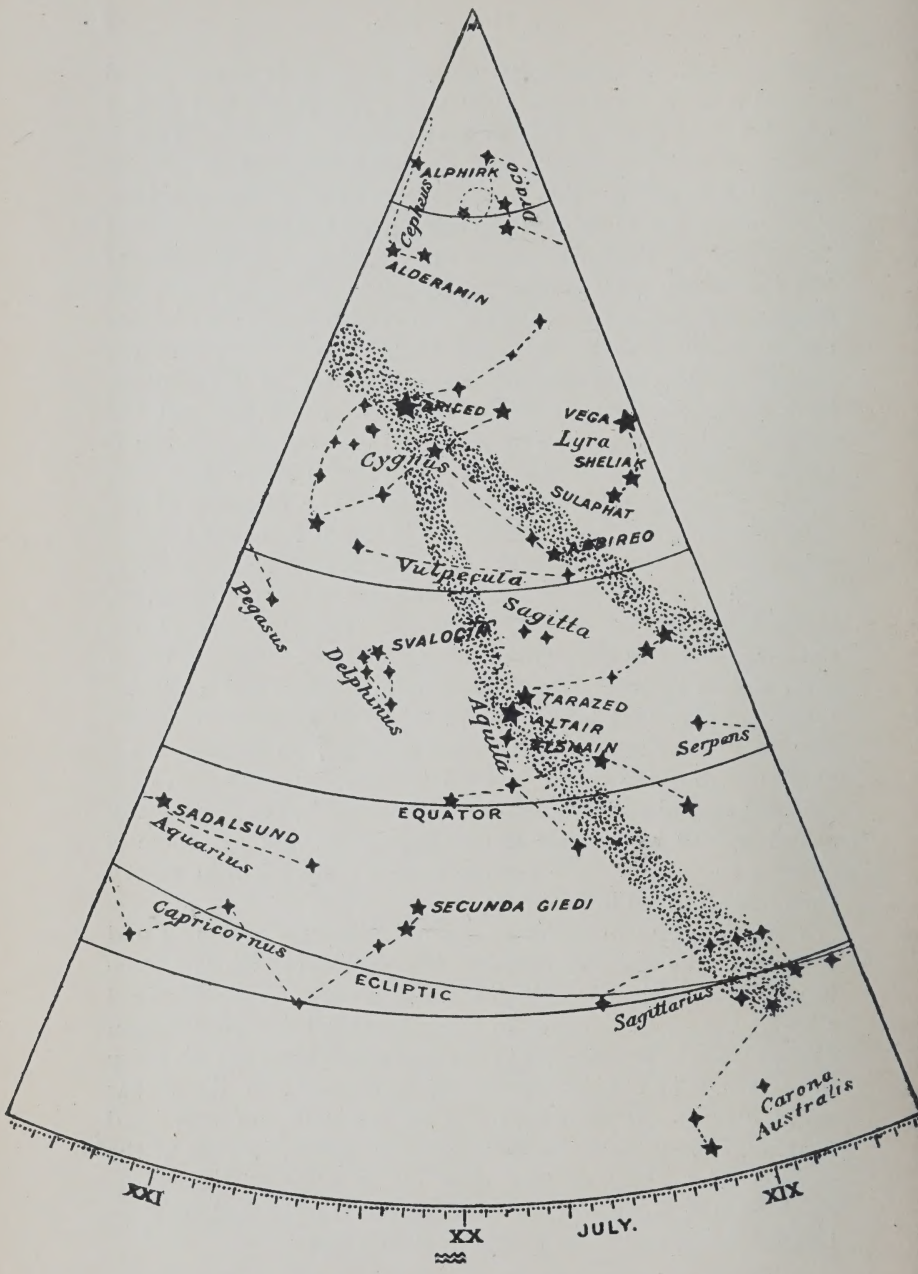
Lyra has the bright star of first magnitude Vega. The famous annular or ring nebula is also in this constellation. Delphinus is an ancient group but neither large nor bright. It is situated 20° east of Altair, and marked by a rhombus shaped figure having the lugubrious name of " Job's Coffin."

Capricorn is lying along the ecliptic in this section. It has a double star which can be detected with the naked eye, Algiedi, prima and secunda, lying in the line of the Altair trio. The lower solstice was originally in Capricorn, and the tropical circle still retains the name.

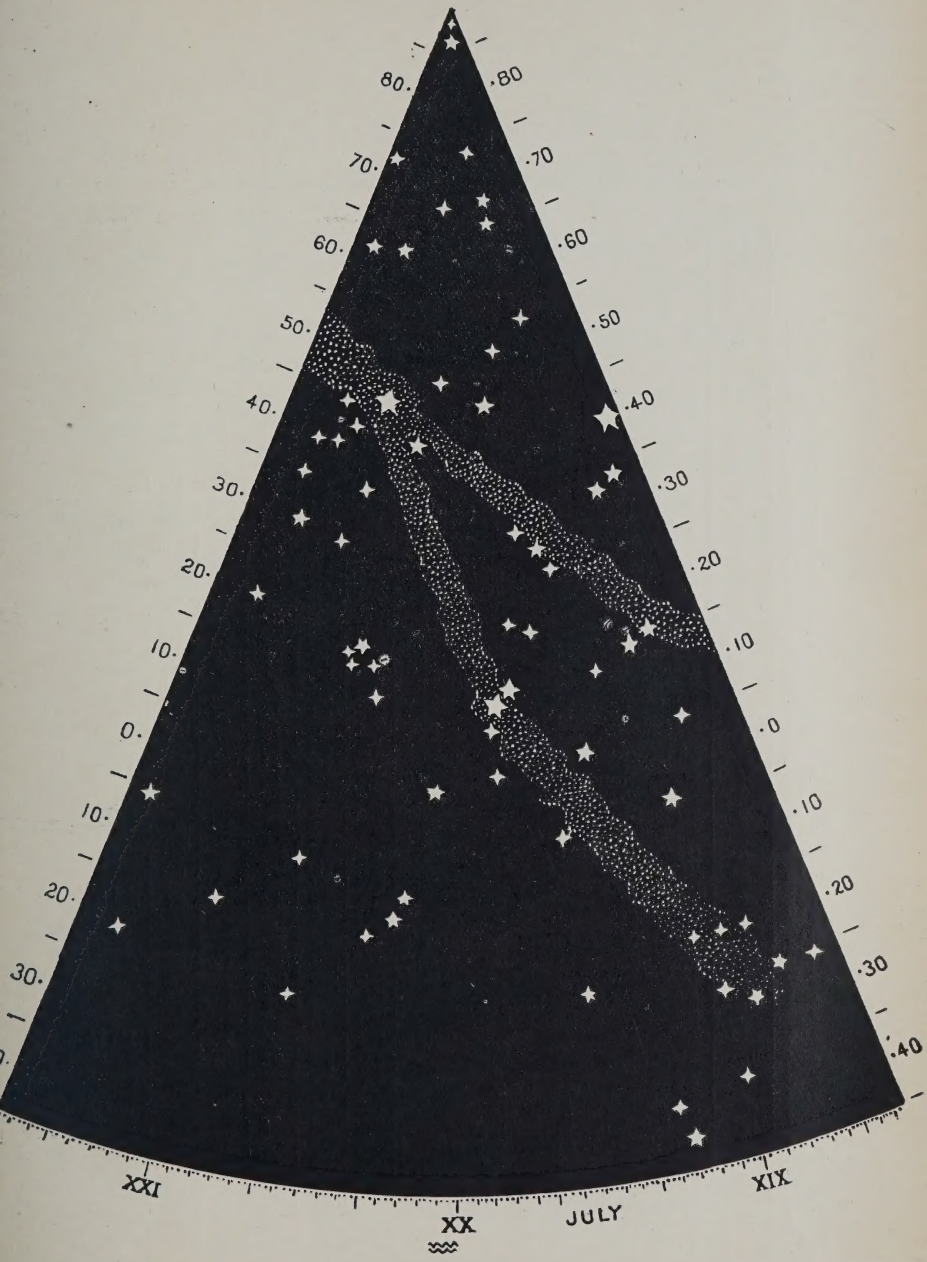
The Milky Way comes into prominence in this segment because of being divided into two long and nearly parallel streams. It has a hazy subdued brightness which gives it the colloquial name it bears, though it is better described by its more dignified name, " the Galaxy." It goes completely round the heavens in an irregular way, although generally keeping the path of a great circle, and varying in breadth and brightness with occasional

dark patches. Although its general hazy appearance would suggest a nebulous structure yet it is a remarkable fact that it contains very little if any of that gaseous material. This is made still more remarkable by the proofs afforded of the nebulae increasing in number just in proportion to their distance from the Galactic circle ; and on the other hand the stars increase in number as they lie nearer to that luminous belt. As a matter of fact the Galaxy itself as observed by telescope, spectroscope and camera, is composed of swarms of stars which from their distance are all reduced to small magnitudes. The Ecliptic and the Galaxy intersect each other twice at points near the two solstices, both being great circles of the heavens. From this fact the comparison was suggested by Herschell that the solar system is to the ecliptic as the stellar universe is to the Milky Way, that is, the universal orbit of all the stars. The diameter of the complete circle has been variously put as not less than twenty, thirty or forty thousand light years, and it may be much more, but there are no means of ascertaining this even approximately, much less the gulf of space beyond. The structure of the universe, so far as observation may suggest conclusions, which must always be tentative, would require a centre and a circumference, seeing that movement in circles is found everywhere. The Milky Way may be a circumference, though perhaps not a boundary, but the centre is hard to find. The old idea of a monster central sun situated in the Pleiades has been generally abandoned as improbable if not impossible. As yet there is nothing so good or more definite in any truly scientific theory than what is given in Psalm XCIII.

The origin and duration of the universe, the beginning and the end of the material creation, is a problem which cannot be brought within the compass of research on such a circumscribed scale as the earth's orbit. In looking beyond the solar system science tends to prove unity in the whole structure, and diversity in details. The great variety of forms seen in the stellar world corresponds with that endless originality of individual form seen everywhere else in nature, no two forms even of the same species being exactly alike. This creative freedom is inexhaustible, so that there is no getting to the end of it to balance things and come to any final conclusion.



KEY TO SEGMENT VII.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SEGMENT VII.

STARS IN SEGMENT VII.

Asterisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	Name of Constellation.	Magnitude.	R.A.			Decl.	
*390	α	Lyrae (*Vega*), ...	0.2	18	33	N	38	41
391	ϕ	Sagittarii, ...	3.3 v.	18	39	S	27	5
*392	β^1	Lyrae (*Sheliak*), ...	3.4 4.5	18	46	N	33	15
393	σ	Sagittarii, ...	2.3	18	49	S	26	24
*394	θ^1	Serpentis, ...	4.7	18	51	N	4	4
395	ξ^2	Sagittarii, ...	3.5	18	52	S	21	13
396	ϵ	Aquilae, ...	4.1	18	55	N	14	56
397	γ	Lyrae (*Sulaphat*), ...	3.2	18	55	N	32	33
398	ζ	Sagittarii, ...	2.9	18	56	S	30	0
399	o	,, ...	3.9	18	59	S	21	52
400	ζ	Aquilae, ...	3.1	19	1	N	13	43
401	λ	,, ...	3.6	19	1	S	5	1
402	τ	Sagittarii, ...	3.5	19	1	S	27	48
403	α	Coronae Austr., ...	4.2	19	3	S	38	2
404	π	Sagittarii, ...	3.1	19	4	S	21	10
405	δ	Draconis, ...	3.2	19	12	N	67	29
406	ω	Aquilae, ...	5.1	19	13	N	11	25
407	β^1	Sagittarii, ...	3.8	19	15	S	44	38
408	κ	Cygni, ...	3.9	19	15	N	53	11
409	α	Sagittarii (*Kaus Australis*),	4.0	19	17	S	49	48
410	τ	Draconis, ...	4.5	19	17	N	73	11
411	δ	Aquilae, ...	3.5	19	20	N	2	55
412	π	Draconis, ...	4.6	19	20	N	65	32
413	α	Vulpeculae, ...	4.7	19	24	N	24	28
*414	β	Cygni (*Albireo*), ...	3.1	19	26	N	27	45
415	h^2	Sagittarii, ...	4.6	19	31	S	25	5
416	κ	Aquilae, ...	4.7	19	31	S	7	10
417	θ	Cygni, ...	4.6	19	33	N	50	50
418	ϕ	,, ...	4.9	19	35	N	29	56
419	α	Sagittae, ...	4.3	19	36	N	17	47
420	λ	Ursae Minoris, ...	6.5	19	15	N	89	0
421	γ	Aquilae (*Tarzed*), ...	2.8	19	41	N	10	23
422	δ	Cygni, ...	3.0	19	42	N	44	53
423	δ^2	Sagittae, ...	3.7	19	43	N	18	18
424	α	Aquilae (*Altair*), ...	1.0	19	46	N	8	37
425	η	Aquilae, ...	3.9	19	47	N		45
426	β	,, (*Alshain*), ...	4.0	19	50	N	6	10
427	ρ	Draconis, ...	4.6	20	2	N	67	32
428	θ	Aquilae, ...	3.4	20	6	S	1	5
*429	o^2	Cygni, ...	3.8	20	10	N	46	27
430	α^2	Capricorni (*Secunda Ciedi*),	3.8	20	12	S	12	49
431	β	Capricorni, ...	3.4	20	15	S	15	4
432	γ	Cygni, ...	2.3	20	18	N	39	57
*433	ρ	Capricorni, ...	5.0	20	23	S	18	7

No.	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
434	ϵ	Delphini, ...	4.1	20	28	N	10	59
435	β	,, ...	3.7	20	33	N	14	16
436	α	,, ...	4.0	20	35	N	15	34
437	α	Cygni (*Deneb or Aridid*), ..	1.5	20	38	N	44	56
438	δ	Delphini, ...	4.6	20	39	N	14	44
439	ψ	Capricorni, ...	4.3	20	40	S	25	36
*440	γ	Delphini, ...	4.6	20	41	N	15	47
441	ϵ	Aquarii, ...	3.8	20	42	S	9	49
442	ϵ	Cygni, ...	2.7	20	42	N	33	37
443	η	Cephii, ...	3.6	20	43	N	61	28
444	32	Vulpeculae, ...	5.1	20	50	N	27	42
445	ν	Cygni, ...	4.1	20	53	N	40	48
446	θ	Capricorni, ...	4.3	21	0	S	17	35
447	ξ	Cygni, ...	3.7	21	1	N	43	33
*448	61^1	,, ...	5.5	21	2	N	38	17
449	ζ	,, ...	3.5	21	8	N	29	50
450	o	,, ...	4.3	21	13	N	38	59
451	υ	,, ...	4.4	21	14	N	34	30
452	α	Cephii (*Alderamin*), ..	2.6	21	16	N	62	11
*453	ι	Pegasi, ...	4.3	21	17	N	19	24
454	ζ	Capricorni, ...	3.8	21	21	S	22	48
455	β	Aquarii (*Sadalsund*), ..	3.1	21	26	S	5	58
*456	β^2	Cephii (*Alphirk*), ...	3.4	21	27	N	70	8

DESCRIPTION OF SEGMENT VIII.

The boundary ribs of this segment have already been described. They enclose the large constellation of Pegasus, having the significant "great square," which is supposed to resemble the body of the winged horse. The positions of the upper stars of the square, Alpharet and Scheat, continue the sweeping curve of Andromeda, while Algenib and Markab are the corresponding stars on the lower side of the square. The one half of Pisces is in this segment, containing the constructive "first point of Aries," which is the present point of the Vernal equinox. Aquarius being of the Zodiac, lies along the ecliptic. It is much extended beyond its true limits, and overlaps Capricorn to the extent of two-thirds of its length.

Piscis Australis, the southern fish, is a small constellation lying low down in the horizon. Its obscurity is relieved by the bright first magnitude star Fomalhaut, usually called

Fomalo. This constellation is not to be confounded with the Zodiacal sign of the same name : it has only one fish, whereas the other has two.

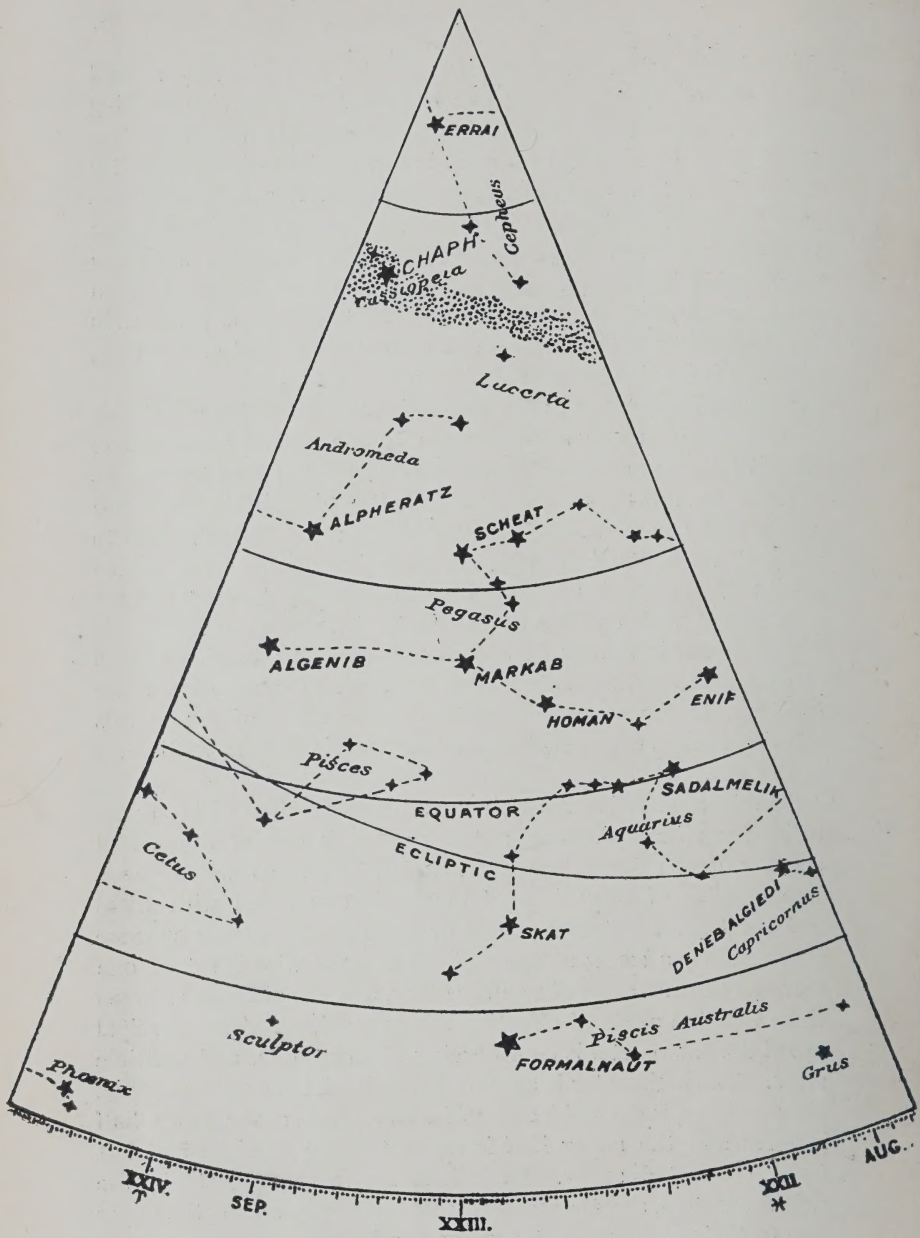
OBSERVATORY INSTRUMENTS.

The first point of Aries is situated in this segment, the beginning and the ending of useful observation ; the sign of the Ram's horns marks it out in the hour circle. When this point is on the Meridian the twenty-four hours of the stellar day begin, and the stars are all related to it by their right ascension. For the correct observation of the " southing " of the stars as they cross the Meridian three instruments of great precision are necessary—a transit telescope, an astronomical clock, and a chronograph ; these constitute the *sine qua non* of an Observatory. The transit instrument is set upon a pedestal built up from the solid rock so as to avoid the vibration of the ground and secure, as near as possible, absolute steadiness. It is usually a large instrument like a cannon provided with trunnions, which are set in bearings standing due east and west, so that the instrument itself moves only up and down and precisely on the Meridian of the place. The stars all pass this north and south line in their apparent diurnal motions, and are brought into the field of view by the graduated circle for adjusting the telescope to their declinations. The eyepiece is furnished with a reticle (net work) of spider threads and illuminated by a small lamp. Looking through the telescope these threads are magnified and appear like wires set in a row in upright position, with a cross section of two wires which form a horizontal path for the star as it passes along just like a spider in its web. As it crosses each of the upright wires (five or more) the time is particularly noted, and the mean afterwards calculated as the precise time of the transit. The astronomical clock is near at hand with its dial showing the twenty-four hours and its pendulum beating seconds. In former times the beats had to be listened for and counted by the observer, but now an electric arrangement is made which gives more accuracy by the beat of the pendulum being recorded on the revolving drum of the chronograph. As the drum revolves once in a minute a marking pen draws a continuous

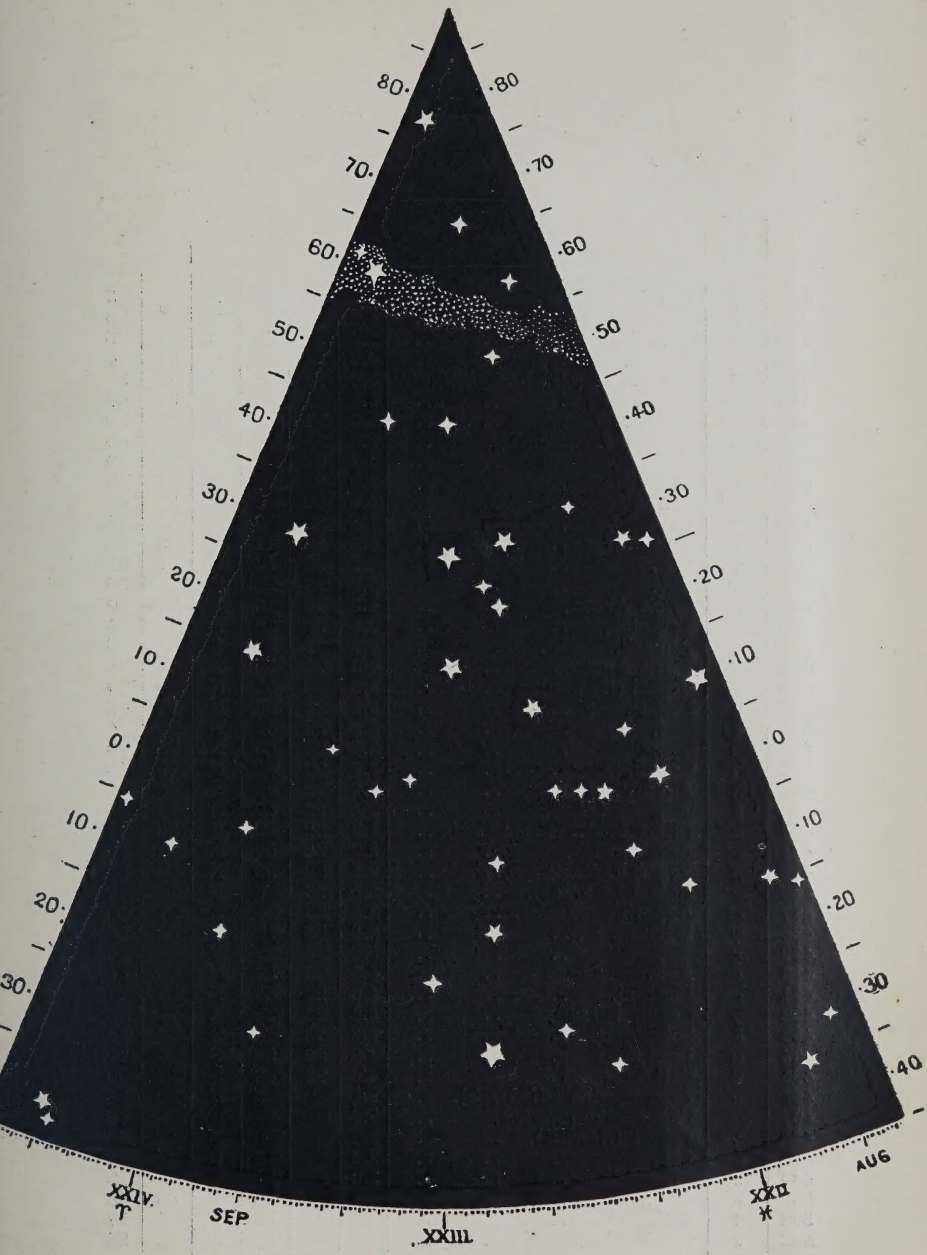
line of circles in spiral along the length, and at every second beat of the pendulum the pen is jerked to one side making a mark. The observer watching the star in the transit instrument holds in his hand an electric key which is independently connected with the pen of the chronograph. As the star passes each of the wires the key is pressed, causing an additional jerk of the pen and showing the exact instant on the drum when the observation was made. The graduated card of the drum, with the marked seconds and interpolated interruptions, gives with great accuracy to the fraction of a second the transit of the star, and this is its right ascension.

Next in importance to the transit instrument is the equatorial telescope, which also works along with the siderial clock. The transit telescope affords only a momentary glimpse of the star as it passes by, but the equatorial follows it up, keeping it constantly and steadily in view. It has two pivots; the first attached to the instrument itself, by which it has a free up and down movement; the second is attached to the first at right angles and set in a socket which points to the pole. The movement on this second pivot is always in accordance with the turning of the earth on its axis, regulated by clock-work to exactly the same rate, but in the opposite direction. The effect of the earth's rotation is thus counteracted, and the star is seen as motionless in the sky.

Certain accessories are adjusted to the eyepiece of the equatorial for special purposes; the camera is one of these, and another called the micrometer, which is not so well known. The interior of this piece of mechanism is fitted with wires like the transit instrument, one or more fixed and one or more moveable by a screw at the end. The fixed wire is set on one star and the moveable one on the other, and the distance between them and the angle of direction are determined. The principal use of the micrometer is for observing binary, triple, and multiple stars. The heliometer is another invention for the same purpose. Its specialty is an object glass in two pieces; the lower half is fixed and the upper half is made to slide to right and left by a graduated screw. Each half shows the objects in the field separately, and the measurement is made by sliding the upper one to their common centre, when the images appear as one.



KEY TO SEGMENT VIII.



SEGMENT VIII.

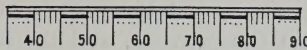
STARS IN SEGMENT VIII.

Asterisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	Name of Constellation.	Magnitude.	R.A			Decl.	
457	γ	Capricorni, ...	3.8	21	34	S	17	5
458	ι	Piscis Austr., ...	4.2	21	39	S	33	26
459	ϵ	Pegasi (*Enif*), ...	2.4	21	39	N	9	26
*460	κ	Pegasi, ...	4.2	21	40	N	25	4
461	δ	Capricorni (*Deneb Algiedi*),	3.0	21	41	S	16	32
462	γ	Gruis, ...	3.0	21	48	S	37	47
463	16	Pegasi, ...	5.0	21	48	N	25	29
464	α	Aquarii (*Sadalmelik*), ..	3.2	22	1	S		46
465	ι	Aquarii, ...	4.3	22	1	S	14	19
466	θ	Pegasi, ...	3.8	22	5	N	5	43
467	π^2	,, ...	4.4	22	5	N	32	43
468	ζ	Cephii, ...	3.5	22	7	N	57	44
469	θ	Aquarii, ...	4.3	22	11	S	8	14
470	γ	,, ...	4.1	22	16	S	1	51
*471	ζ	,, ...	3.8	22	24	S		30
472	β	Piscis Austr., ...	4.3	22	26	S	32	50
473	α	Lacertae, ...	3.9	22	28	N	49	47
474	η	Aquarii, ...	4.2	22	30	S		35
475	ϵ	Piscis Austr., ...	4.0	22	35	S	27	31
476	ζ	Pegasi (*Homan*), ...	3.6	22	36	N	10	20
477	η	Pegasi, ...	3.1	22	38	N	29	43
478	λ	,, ...	4.2	22	42	N	23	4
479	μ	,, ...	3.7	22	45	N	24	6
480	ι	Cephii, ...	3.6	22	45	N	65	42
481	λ	Aquarii, ...	3.8	22	49	S	8	4
482	δ	,, (*Skat*), ...	3.4	22	49	S	16	18
483	α	Piscis Austr. (*Fomalhaut*), ..	1.3	22	52	S	30	6
484	o	Andromedae, ...	3.8	22	57	N	41	49
485	β	Pegasi (*Scheat*), ...	2.6	22	59	N	27	34
486	α	Pegasi (*Markab*), ...	2.6	23	0	N	14	42
487	c^2	Aquarii, ...	3.6	23	4	S	21	40
488	γ	Piscium, ...	3.8	23	12	N	2	46
489	κ	,, ...	5.0	23	22	N		44
490	ι	Andromedae, ...	4.3	23	33	N	42	44
491	ι	Piscium, ...	4.3	23	35	N	5	7
492	γ	Cephii (*Errai*), ...	3.4	23	35	N	77	6
493	δ	Sculptoris, ...	4.6	23	44	S	28	38
494	ω	Piscium, ...	4.2	23	54	S	6	20
495	2	Ceti, ...	4.6	23	58	S	17	50
496	α	Andromedae (*Alpheritz*), ..	2.1		3	N	28	34
497	β	Cassiopeiae (*Chaph*), ..	2.4		4	N	58	37
498	γ	Pegasi (*Algenib*), ...	3.0		8	N	14	39
499	ι	Ceti, ...	3.6		14	S	9	20
500	κ	Phoenicis, ...	3.9		21	S	44	12
501	α	,, ...	2.4		21	S	42	48
502	12	Ceti, ...	6.2		25	S	4	27
503	κ	Cassiopeiae, ...	4.2		27	N	62	24

CHAPTER III.

SOUTH CIRCUMPOLAR STARS.

Scale of  degrees.

This region of the sky is directly opposite the north circumpolar region and therefore can only be seen in the southern hemisphere in latitudes corresponding to that of the British

Isles. From this new point of view everything appears to be reversed ; the apparent motions of the stars at night, and of the sun during the day, are from right to left, instead of from left to right as in the north, and the pole is in the south. New stars also appear in the heavens, and the old familiar constellations do not rise above the horizon, except at certain seasons when they show a small part of their outline. The handle of the plough for instance is sometimes seen, but never the pointers. The South Pole has its pointers, however, in another constellation very characteristic of the southern skies, the Southern Cross. Its two principal stars Alpha and Gamma point to Sigma the South Pole star, a rather dim one, only of fifth magnitude, in the constellation of Octans. There are only five stars of first magnitude in this extreme portion of the starry firmament, and only two of them have names of their own—Canopus in Argo Navis (the ship), and Achernar in Eridanus (the river). Alpha of the Centaur is the third, and up to the present time this star is the nearest neighbour to the solar system, being three and a half light years distant ; the other two stars of first rank are Alpha of the Southern Cross, and Beta of the Centaur.

In no other region of the sky does the Milky Way shine out so brightly as in the south, and it is much more variegated with light and shade than it is elsewhere ; dark patches and broken up contour lines run all through and around it. The most striking and famous of these is " the Coal Sack," the name applied to a dark inky portion of oval shape quite near the Southern Cross. Another unique feature of the southern skies is the Magellanic Clouds, which look like detached portions of the Milky Way. They are composed of nebulous clusters of stars, and are known by the names of Nebecula Major and Minor.

The constellations of the southern hemisphere are all of modern designation, dating from the beginning of the seventeenth century onwards, when the discoveries of the early navigators led them into the southern seas. The groupings were made in the same arbitrary manner as in the north, such as were dictated by the fancy of the men who first saw them and gave them names. In considering the diagram of the south circumpolar stars it has to be observed that the hours and months go round in the opposite way in accordance with the inverted standpoint of the observer.

CATALOGUE OF SOUTH CIRCUMPOLAR CONSTELLATIONS.

Asterisks before Numbers denote Double, Triple, or Multiple Stars.

No.	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
1	o	Octantis, ...	7.2		12	S	88	52
2	ζ	Toucani, ...	4.3		15		65	25
3	β	Hydri, ...	2.9		20		77	46
4	α	Phoenicis, ...	2.4		21		42	48
5	β	,, ...	3.4	1	1		47	13
6	γ	,, ...	3.3	1	24		43	47
7	α	Eridani, ...	0.5	1	34		57	42
8	α	Hydri, ...	3.0	1	55		62	1
9	ϕ	Eridani, ...	3.7	2	13		51	56
10	δ	Hydri, ...	4.2	2	20		69	4
11	θ	Eridani, ...	3.0	2	54		40	40
12		B A C 972, ...	5.3	3	1		60	7
13		B A C 1106, ...	5.6	3	29		50	41
14	γ	Hydri, ...	3.1	3	48		74	31
15	α	Horologii, ...	3.8	4	10		42	31
16	α	Reticuli, ...	3.4	4	13		62	42
17	α	Doradus, ...	3.5	4	31		55	14
18		B A C 1740, ...	5.6	5	27		47	8
19	β	Doradus, ...	3.7	5	32		62	33
20	β	Columbae, ...	3.1	5	47		35	47
21	α	Argus, ...	0.4	6	21		52	38
*22	ν	,, ...	3.2	6	34		43	6
23	α	Pictoris, ...	3.3	6	47		61	50
24	τ	Argus, ...	2.8	6	47		50	30
25	π	,, ...	2.7	7	13		36	55
26	δ	Volantis, ...	3.9	7	16		67	47
27	σ	Argus, ...	3.5	7	26		43	6
28	α	Carinae, ...	4.9	7	33		58	19
29	A	Octantis, ...	7.8	7	52		88	35
30	ζ	Argus, ...	2.3	8	0		39	44
31	γ	,, ...	1.9	8	6		47	3
32	ϵ	,, ...	1.7	8	20		59	12
33	δ	,, ...	2.0	8	42		54	22
34	λ	,, ...	2.5	9	4		43	3
35	β	,, ...	2.0	9	12		69	20
36	κ	,, ...	2.7	9	27		54	36
37	ψ	,, ...	3.7	9	28		40	3
38	N	Velorum, ...	3.2	10	10		56	37
39	q	,, ...	4.0	10	13		41	39
40	q	Carinae, ...	3.3	10	39		60	52
41	θ	Argus, ...	3.0	10	39		63	54
42	n	,, ...	var, $1.7\frac{1}{2}$	10	41		59	11
43	μ	,, ...	2.8	10	42		48	55
44		B A C 3755	5.1	10	52		36	36
45	n	Octantis, ...	6.2	10	59		84	5
46	λ	Centauri, ...	3.3	11	31		62	30
47		B A C 4007, ...	5.0	11	46		44	37
48	δ	Centauri, ...	2.8	12	3		50	12
49	δ	Crucis, ...	3.1	12	10		58	13

No.	Greek letter.	NAME OF CONSTELLATION.	Magnitude.	R.A.			Decl.	
50	β	Chamaeleontis, ...	4.3	12	12		78	47
*51	α^1	Crucis, ...	1.0	12	21		62	35
*52	γ	,, ...	1.6	12	26		56	35
53	α	Muscae, ...	2.9	12	31		68	37
54	γ	Centauri, ...	2.4	12	36		48	26
*55	β	Muscae, ...	3.3	12	40		67	35
56	β	Crucis, ...	1.5	12	42		59	10
57	ι	Centauri, ...	3.0	13	15		36	13
58	ϵ	,, ...	2.6	13	33		52	59
59	μ	,, ...	3.3	13	44		42	—
60	ζ	,, ...	2.8	13	49		46	49
61	β	,, ...	0.8	13	57		59	55
62	θ	,, ...	2.1	14	1		35	54
63	n	,, ...	2.7	14	29		41	44
64	α^2	,, ...	1.0	14	33		60	26
*65	α	Circini, ...	3.4	14	34		64	34
66	α	Lupi, ...	2.5	14	35		46	59
67	β	,, ...	2.7	14	52		42	45
68	κ	Centauri, ...	3.3	14	53		41	43
69	ζ	Lupi, ...	3.5	15	5		51	44
70	γ	Trianguli Aust., ...	3.0	15	10		68	20
71	ρ	Octantis, ...	5.7	15	21		84	9
72	γ	Lupi, ...	3.0	15	28		40	51
73	β	Trianguli Aust., ...	3.1	15	46		63	8
74	γ^2	Normae, ...	4.2	16	12		49	55
75	α	Trianguli Aust., ...	1.9	16	38		68	51
76	ζ	Arae, ...	3.0	16	50		55	50
77	β	,, ...	2.7	17	17		55	26
78	υ	Scorpii, ...	2.8	17	24		37	13
79	α	Arae, ...	2.9	17	24		49	48
80	λ	Scorpii, ...	1.8	17	27		37	2
81	θ	,, ...	2.0	17	30		42	56
82	κ	,, ...	2.6	17	36		38	58
83	n	Pavonis, ...	3.5	17	36		64	40
84	ι^1	Scorpii, ...	3.1	17	41		40	5
85	n	Sagittarii, ...	3.1	18	11		36	47
86	α	Telescopii, ...	3.7	18	20		46	1
87	λ	Pavonis, ...	4.4	18	43	S	62	17
88	σ	Octantis, ...	5.5	19	1		89	14
89	α	Coronae Aust., ...	4.2	19	3		38	2
90		B A C 6632, ...	5.4	19	20		54	30
91	ι	Sagittarii, ...	4.1	19	48		42	6
92	δ	Pavonis, ...	3.6	19	59		66	25
93	α	,, ...	2.0	20	18		57	2
94	β	,, ...	3.5	20	36		66	32
95	θ	Microscopii, ...	5.0	21	14		41	12
96	γ	Pavonis, ...	4.2	21	18		65	47
97	γ	Gruis, ...	3.2	21	48		37	47
98	α	,, ...	1.9	22	2		47	24
99	α	Toucani, ...	2.9	22	12		60	43
100	β	Gruis, ...	2.1	22	37		47	22
101	ϵ	,, ...	3.7	22	42		51	48
102	γ	Toucani, ...	4.0	23	12		58	44
103	ι	Phoenicis, ...	4.9	23	30		43	7

KEY MAP OF STAR UMBRELLA.

CHAPTER IV.

KEY TO UMBRELLA STAR MAP.

Besides the general rules given on page 11 for adjusting the Umbrella Star Map by the Meridian, there are other ways in which it can be used applicable to the two circumpolar regions. The eight ribs of the umbrella divide the hours I., IV., VII., X., XIII., XVI., XIX., and XXII., so that when any one of the ribs is pointed due north the hours at which the sky presents a particular appearance are at once indicated for the 1st and 15th of all the months of the year. The following table will show this in full detail. In order to find out what the aspect of the sky will be for any particular night between the beginning of the month and the 15th, it has only to be remembered that the stars arrive at the same point 3 minutes 56 seconds earlier every night, so that this time has to be added to the right ascension time given at the previous rib for every later date up to the night in question. The numbering of the ribs is from the one nearest the first point of Aries, which is to be considered number one, and the rotation is according to the hours on the right ascension circle.

The hour circle is used along with the declination scale for designating the positions of stars; but for general observation it is always the scale of degrees that is used as the measuring rule. The circle is divided into 360 equal parts called degrees (°), each degree is divided into 60 minutes (′), and the minutes into 60 seconds (″), called seconds of arc, to distinguish them from seconds of time. Smaller divisions than these are made by means of the decimal point, which is always required in dealing with the parallax of fixed stars, the angles of which never amount to one second. The mariner's compass affords a good illustration of how the circle is divided. The four cardinal points mark quadrants which are 90°; the intermediate points divide the quadrants into two, 45° each; the third series of points make $22\frac{1}{2}$°, and the fourth series—"the 32 points of the compass," $11\frac{1}{4}$°. Half points of $5\frac{1}{8}$° are also marked off, and generally this is sufficiently precise for ordinary navigation; but with the advance of scientific instruments and the introduction of steam steering gear large vessels can now be steered to single degrees of the circle.

TABLE for indicating the ASPECT of the HEAVENS during the twelve months of the year at any particular Hour.

	I.	IV.	VII.	X.	XIII.	XVI.	XIX.	XXII.	
Hours	1 RIB. R.A. 0-30	2 RIB. R.A. 3-30	3 RIB. R.A. 6-30	4 RIB. R.A. 9-30	5 RIB. R.A. 12-30	6 RIB. R.A. 15-30	7 RIB. R.A. 18-30	8 RIB. R.A. 21-30	Hours
XII. Midnight,	Oct. 1	Nov. 15	Jan. 1	Feb. 15	Apr. 1	May 15	July 1	Aug. 15	XII. Noon.
XI. P.M.,	,, 15	Dec. 1	,, 15	Mar. 1	,, 15	June 1	,, 15	Sept. 1	XI. A.M.
X. ,,	Nov. 1	,, 15	Feb. 1	,, 15	May 1	,, 15	Aug. 1	,, 15	X. ,,
IX. ,,	,, 15	Jan. 1	,, 15	Apr. 1	,, 15	July 1	,, 15	Oct. 1	IX. ,,
VIII. ,,	Dec. 1	,, 15	Mar. 1	,, 15	June 1	,, 15	Sept. 1	,, 15	VIII. ,,
VII. ,,	,, 15	Feb. 1	,, 15	May 1	,, 15	Aug. 1	,, 15	Nov. 1	VII. ,,
VI. ,,	Jan. 1	,, 15	Apr. 1	,, 15	July 1	,, 15	Oct. 1	,, 15	VI. ,,
V. ,,	,, 15	Mar. 1	,, 15	June 1	,, 15	Sept. 1	,, 15	Dec. 1	V. ,,
IV. ,,	Feb. 1	,, 15	May 1	,, 15	Aug. 1	,, 15	Nov. 1	,, 15	IV. ,,
III. ,,	,, 15	Apr. 1	,, 15	July 1	,, 15	Oct. 1	,, 15	Jan. 1	III. ,,
II. ,,	Mar. 1	,, 15	June 1	,, 15	Sept. 1	,, 15	Dec. 1	,, 15	II. ,,
I. ,,	,, 15	May 1	,, 15	Aug. 1	,, 15	Nov. 1	,, 15	Feb. 1	I. ,,
XII. Noon,	Apr. 1	,, 15	July 1	,, 15	Oct. 1	,, 15	Jan. 1	,, 15	XII. Midnight.
XI. A.M.,	,, 15	June 1	,, 15	Sept. 1	,, 15	Dec. 1	,, 15	Mar. 1	XI. P.M.
X. ,,	May 1	,, 15	Aug. 1	,, 15	Nov. 1	,, 15	Feb. 1	,, 15	X. ,,
IX. ,,	,, 15	July 1	,, 15	Oct. 1	,, 15	Jan. 1	,, 15	Apr. 1	IX. ,,
VIII. ,,	June 1	,, 15	Sept. 1	,, 15	Dec. 1	,, 15	Mar. 1	,, 15	VIII. ,,
VII. ,,	,, 15	Aug. 1	,, 15	Nov. 1	,, 15	Feb. 1	,, 15	May 1	VII. ,,
VI. ,,	July 1	,, 15	Oct. 1	,, 15	Jan. 1	,, 15	Apr. 1	,, 15	VI. ,,
V. ,,	,, 15	Sept. 1	,, 15	Dec. 1	,, 15	Mar. 1	,, 15	June 1	V. ,,
IV. ,,	Aug. 1	,, 15	Nov. 1	,, 15	Feb. 1	,, 15	May 1	,, 15	IV. ,,
III. ,,	,, 15	Oct. 1	,, 15	Jan. 1	,, 15	Apr. 1	,, 15	July 1	III. ,,
II. ,,	Sept. 1	,, 15	Dec. 1	,, 15	Mar. 1	,, 15	June 1	,, 15	II. ,,
I. ,,	,, 15	Nov. 1	,, 15	Feb. 1	,, 15	May 1	,, 15	Aug. 1	I. ,,

Note.—When the particular rib is pointed due South the hours indicated will be those in the left hand column. When pointed due North the hours are those in the right hand column.

THE ITINERARY.

If the strands of space and time,
Could be twisted into rhyme,
Then their story might be told,
Like a mystic scroll unrolled.

First of all the constellations
Grouped together in their stations,
Ursa Major, rising high
Circles round the midnight sky.

Bearing Northward, almost due,
Guided by the *pointers* two,
Fixed among the glittering host
Stands the *Pole Star* at his post.

Round the pole the *Dragon* holds
All, within his sinewy folds ;
Watching from the central hub
Mighty *Hercules* with his club.

At a distance from the *Bear*
Seated in the lady's chair,
Cassiopeia watches here
For the coursing Charioteer.

Cepheus the King, is known
By a lozenge near his throne ;
Perseus, by a "segment" limb
Near the circumpolar rim,

Now *Capella* may be found
With her kids, a short way round ;
While across the starry sphere
Vega shines with lustre clear.

Moving down through stellar space
Soon is found *Orion's* place ;
There he stands in stately pride !
Sword and buckler by his side.

On his shoulder *Betelgeux*,
Rigel—buckle of his shoe ;
Starry clusters near at hand,
Pleiades—a glittering band.

Through the belt a line is drawn
Pointing to *Aldebaran ;*
Downward let the line be traced,
Near it *Sirius* will be placed.

Pegasus—a spacious square
For *Andromeda* the fair.
Cygnus has a cross to lay
On the dreamy Milky Way.

Look down from the winged horse,
Fomalhaut is seen of course ;
Look again across the square,
There you see the bright *Altair*.

Distant from the *Dragon's* eyes
Far below, the *Scorpion* lies ;
In his head *Antares* gleams
Red, like *Mars*, with rival beams.

Next the *Northern Crown* is shown
Radiating in the zone ;
With the " gem " in circlet bright,
Fairest jewel of the night.

Sweeping downwards from the Plough
There *Arcturus* meets you now ;
Still continuing farther through
Mark fair *Spica* in the view.

Regulus the handle took
Of the Lion's reaping hook ;
Leo, wroth at such disaster
Glares at *Pollux* and at *Castor*.

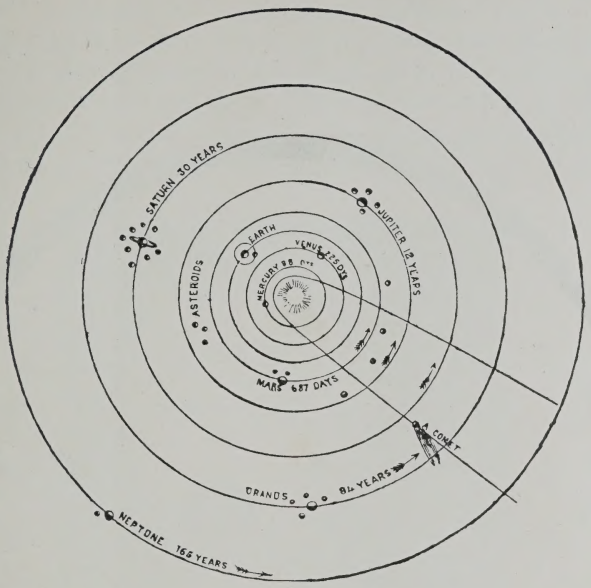
Procyon comes now, to conclude
All of greatest magnitude.
Lesser lights require attention
Declination, Right Ascension.

O ye stars of beauteous light !
Thus I watch you night by night,
Learning from your mystic pages
All the wonders of the ages.

Yet I know not how you shine
With a radiance so divine,
But that All Creating Might
Gave the word, " Let there be light."

CHAPTER V.

THE SOLAR SYSTEM.



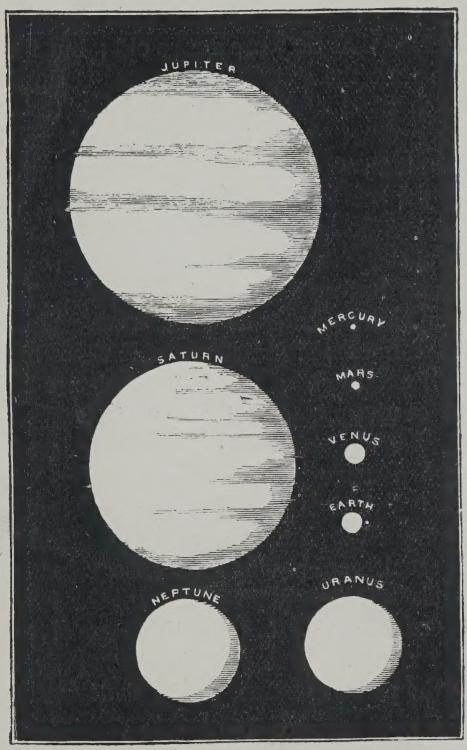
THE Solar System may be described as a family of three generations, of which the Sun is the grandfather, the Planets the children, and the Moons the grand-children. The process of generation is difficult to follow, but the fact of a common origin is borne out by many evidences. They all revolve in nearly the same plane; they are situated at regular intervals of distance from each other, and they are composed of the same substances. They are thus very similar in family likeness, but they are also like the individuals composing a family, very different in other respects, no two of them being exactly alike in size, weight, motion and age. It is not certain which were formed first; some argue that the outer planets Neptune and Uranus have the claim to priority of birth, and others as stoutly affirm the primogeniture of the nearer and smaller ones as Mercury and Venus. The Earth occupies the unique position among them as being the only one adapted for the residence of such a creature as man, everything being nicely adjusted for sustaining life.

Theories have been promulgated from time to time to account for the creation, evolution, and development of the planetary system. It is supposed, for instance, that the whole was, at a remote period of time, a voluminous mass of fiery vapour or gas, having a central nucleus which ultimately became the Sun. In process of a revolving motion, such as is known to be going

Relative Sizes of the Sun and Planets. The *volume* of the Sun exceeds that of the Earth 1,300,000 times, though the *mass*, or quantity of matter contained in it, is only 332,000 times that of the Earth. The Sun's density is only about one quarter of the Earth's density.

on in other Nebulae, subordinate centres were formed in cooler parts of the mass, which incorporated within themselves all the material gravitating to them, and became differentiated one by one into planets. Further, while still in a plastic or semi-liquid

state some of them repeated the process of their own formation by forming rings like Saturn and moons like Jupiter. This theory is supported by many ascertained facts drawn from observation of Nebulae in different parts of the heavens—of which there are very many—such as those in Orion and Andromeda, and the beautiful annular nebula in Lyra, all of which are moving in a circular, spiral or elliptical way, as if in the early stages of their existence as systems similar to our own. Whether



Comparative Sizes of the Principal Planets.

this theory as an explanation of the manner of creation as it was "In the beginning" (Gen. i. 1), be the correct one or not, it has this recommendation that it does not contradict the Scriptural account, but rather agrees with it, up to the time when "the

earth was without form and void (Septuagint, unfurnished), and darkness was upon the face of the deep." The six days or periods coming afterwards was rather the furnishing of the earth than its creation and shows how it was adapted to be the dwelling place of man.

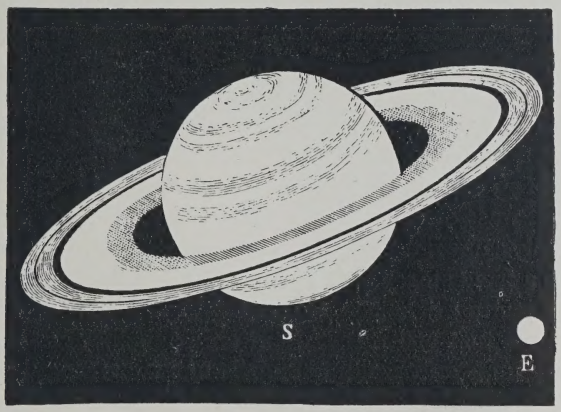
THE MAJOR PLANETS.

The four outer planets, Jupiter, Saturn, Uranus and Neptune, are much larger than the four inner ones, Mercury, Venus, Earth and Mars, but they are not nearly so solid, and because of this some have inferred that they are not so old ; but the explanation may rather be that the solidifying process is slower because of their very much greater bulk. From all the tests that can be brought to bear upon them, it would seem that they are still in a semi-fluid state, with a very high temperature ; their outer surface which we see being a sort of cloudland, their shape is not rigid, but deviating from the true circle to oblateness in Jupiter and oval shape in Uranus. The rotation of the two larger ones Jupiter and Saturn is excessively rapid. Jupiter with a diameter eleven times greater than the earth making a complete revolution in ten hours ; and Saturn, nine times bigger than the earth, but with a system of rings stretching far beyond, taking only a quarter of an hour more than Jupiter.

To the naked eye Jupiter has only brightness to show, but viewed through a telescope it has markings as well defined as the moon, but not of such permanence, for the masses of clouds are ever changing their shape and position. He has five moons —the fifth, a small one, having been discovered in 1892. The four larger ones have been known since the invention of the telescope by Galileo in 1610. The motions of the moons are interesting and useful. These satellites pass in front and behind alternately in the motion of their orbits, their shadows appearing as dark spots on the disc when in front (conjunction), and when passing behind (opposition) they are eclipsed in the deep shadow of the planet. These eclipses occur at intervals exactly the same for all the moons, according to calculation ; but according to observation there is a difference which also applies to them all. It is accounted for by the very large orbit of Jupiter (10 astronomical units), combined with the changing position of the earth

in her annual motion, so that at conjunction she is two astronomical units more distant than at opposition from Jupiter. The appearances and disappearances of the moons in eclipse bring out this difference in distance, by varying as much as seventeen minutes in their calculated time when the distance is greatest than when it is nearest. The explanation is that light takes seventeen minutes to travel two astronomical units, 186,000,000 miles. This divided up gives the velocity of light, which is 186,330 miles per second.

When well placed for observation, Saturn is a conspicuous object in the sky and of singular interest because of its unique system of rings as well as moons. The brightness varies as the phases of the rings proceed in the course of the thirty years orbit. The polarity, which is 27°, sometimes presents the ring-system tilted at an angle to the line of sight from the earth,



Comparative Sizes of Saturn and Earth.

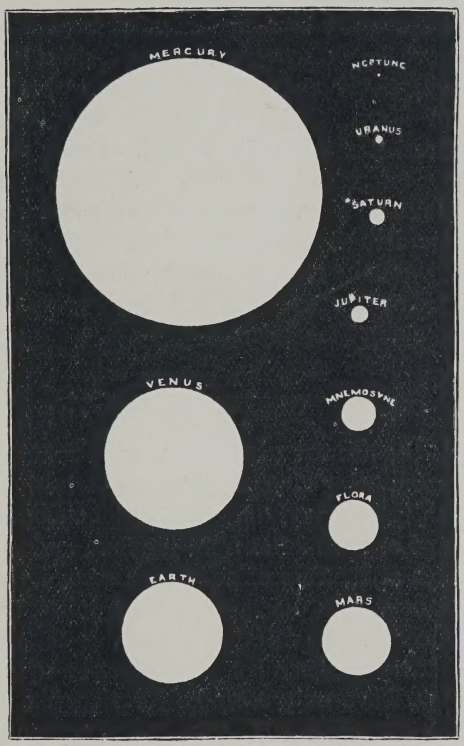
when the illuminated surface is increased; and sometimes only the thin edge of the rings comes into this position, when the reflecting surface is diminished. Only powerful telescopes can make out the rings at all in an edge-view of them. In actual bulk Saturn is 760 times greater than the earth, but its density is only one-eighth as much—not so much as water—so that it must be largely composed of some lighter material than either earth or water, possibly the component elements of both of these, but in a vaporous state.

The surrounding rings are the specialty of Saturn, and, so far as known, no other body in the heavens is furnished with such appendages,. There are three of them, the inner, middle, and outer circles, with a diameter across the whole of 168,000 miles. The outer ring is 10,000 miles broad, then comes a clear space of 1,000 miles dividing it from the middle one, which is 17,000 miles in breadth. The third ring, that nearest the planet, is semi-transparent and 9,000 miles broad, its inner edge being about 10,000 miles distant from the surface of Saturn itself. Comparatively speaking the rings are very thin, about a hundred miles. Their composition is as doubtful as that of the planet, and they cannot be more solid, otherwise the strain of their excessively rapid rotation would break them up. It seems to be established that the outer layers are moving more slowly than the inner ones, which would make a sort of spiral, and in order to fulfil these conditions the composition would have to be Meteoric dust. The shadow cast by the whole ring system is seen on the planet, and *vice-versa*, the shadow of Saturn on the rings. There are eight moons which are chiefly remarkable as showing the extraordinary range of the system, the outer one, Iapetus, being distant from its primary 2½ millions of miles, with a period of 79 days in its orbit, nearly as much as Mercury.

Uranus was discovered by Herschel in 1781. When it accidentally came into the field of his telescope it was at once seen not to be a fixed star. It is 19 astronomical units from the Sun, and has a journey of 84 years to get round its orbit. Its diameter is four times that of the earth, but only a fifth of its density, so that this also is an unsolid body. It has four moons which are chiefly remarkable for the peculiarity of their motions which appear to be backward, the reverse from those of the nearer planets. This peculiarity has not yet been satisfactorily explained. Another peculiarity of Uranus is the fact that it has belts across the surface like Jupiter, but not in lines corresponding with the orbits of the moons.

Neptune was discovered in 1846 by calculation rather than by observation. The disturbance of Uranus in the path of its orbit was so marked that it was assumed there must be another planet in the outer space beyond. Sufficient data were computed so as to show approximately from whence the disturbing influence

was coming, and when the telescope was pointed in that direction Neptune was discovered. It is distant 30 astronomical units from the Sun, with a period of 164 years to go round its orbit, which it does at the rate of $3\frac{1}{3}$ miles a second. These data throw this planet out of the sequence of distances known as "Bode's Law," which applies to all the other planets, and for a



Apparent Size of the Sun as visible from the Eight Primary Planets and two of the Asteroids.

time threw the searchers off the track. When the discovery was made, that law was modified in its force, though not discarded, because of its application to all the other members of the Solar System. Neptune's period of rotation like that of Uranus is unknown. These two planets are like each other in

many of their characteristics, and form a pair like Venus and the Earth. Neptune has only one moon, and it moves in the backward way, from east to west.

In the broad depth of space between the inner and outer planets—between Mars and Jupiter—lie the Asteroids. They are a cluster of very small bodies ranging from 500 miles diameter down to about 20. Their periods in their orbits are from three to nine years according to their distances from the Sun. Over 600 of them have been discovered, but there must be many more, since they collectively exert a marked perturbation upon the movements of Mars. Quite recently a new one, which has been called Eros, has been discovered. It has the distinction of being the nearest neighbour to the Earth, a distinction hitherto attributed to Venus, and ocasionally a wandering Comet. The multitudinous swarm of the Asteroids suggests the idea that they are the remnant of the ancient nebulous condition of the Solar System, the solidified overplus of matter employed in making the planets.

THE MINOR PLANETS.

MERCURY is the nearest to the Sun, and for that reason it is seldom to be seen, being always set before dark when an evening star, and when it is a morning star daylight closely follows its rising. It is 36,000,000 miles from the Sun, and goes round its orbit in 88 days at the rate of 30 miles a second, the quickest of any of the planets. Its diameter is 3,000 miles, less than half the size of the earth. Its rotation period was unknown until the end of last century, when by certain marks upon its surface it was found to have only a single rotation like the Moon in going round both orbit and axis, and consequently always presents the same face to the Sun. Being an inferior planet, that is, between the Earth and the Sun, it has phases like the Moon, ranging from new to full, and passing through all the intermediate stages of crescent, half, and gibbous both in waxing and waning. It has transits over the sun's disc at irregular intervals, but these are of little importance.

Venus is the brightest of all the planets, and has been known to cast a shadow resembling moonlight when at its most

brilliant phase. Its classic and poetic names are of ancient date. It is Phosphorus in the morning and Hesperus in the evening. Its distance from the sun is 67,200,000 miles and comes as near to the earth as 26,000,000 miles, and up till recently was regarded as our nearest neighbour, though now superseded by the newly discovered Asteroid Eros. It has phases like Mercury, and the Moon, first discovered by Galileo in 1610. In this planet we meet with an atmosphere of very decided thickness and density, which shows conspicuously as a bright ring of light when touching the sun's limb in the course of a transit of Venus. Up till recently it was considered to have a rotation on its axis much the same as the earth, though the proofs of it were rather doubtful; and now a system of permanent markings of radiating dark streaks has led to the conclusion that it is like Mercury and the Moon in the manner of its rotation or rather absence of rotation, and turns the same face towards the sun throughout the whole course of its orbit of seven and a half months. The transits of Venus over the Sun's disc are occasions of great interest. They occur at rare intervals, and are taken advantage of for measuring the distance of the Sun.

Mars was known to the ancients as one of the planets or wanderers in the sky, and obtained the name of the heathen god of war from its fiery red colour. It is distant from the sun one and a half astronomical units. It takes a year and ten months to go round its orbit, and being an outer planet it has an apparent retrograde movement at certain parts of its orbit. Its diameter is 4,230 miles, a little more than half that of the earth, and its density about two-thirds. There is no mistake about the rotation of Mars on its axis, for the surface is well marked. Its time of rotation is about forty minutes more than our day of 24 hours. Its polarity is also much the same as the Earth, 24° 50′, one degree more of inclination. Its seasons would therefore be much the same as ours provided its temperature was also the same. It is hardly possible that this can be, unless it has internal resources of heat, of which we do not know, because its distance from the Sun, the great source of heat, is a half more than that of the earth, consequently it would be much colder. As seen through a telescope of high magnifying power the surface is very much variegated with light and dark colouring,

which do not change like those of Jupiter and Saturn. More recently discoveries have been made of a sort of net-work system of markings which have been called canals—though they must be actually very wide to be seen at all at such a distance. At certain regular seasons they broaden out even wider as if vegetation had sprung up along the margins. Mars has two moons, but they are very small. The inner one Phobos, is only about six thousand miles distant from the centre of the planet, and it goes round in about seven hours and a half, less than a third of Mars' day.

THE EARTH, THE SUN AND THE MOON.

THE Earth as a member of the Solar System has its motions in relation to the others, being under the same laws which govern the whole. It is a sphere with a diameter of 7,920 miles, rotating on its axis in twenty-four hours, not upright but inclined at an angle of twenty-three and a half degrees. It goes round the Sun in $365\frac{1}{4}$ days at the rate of $18\frac{1}{2}$ miles a second. As the Earth is the standpoint from which the stars are observed it is more convenient to apply the yearly motion to the Sun calling the ecliptic " the Sun's path " in the heavens. For general purposes it makes no difference as the problems are the same whether the Sun's apparent motion be taken or the earth's proper motion.

The Sun being the centre of the Solar System and the source of all its life and action, while they keep moving round in their orbits he is at the same time bearing them all along with him in his very much greater orbit around a greater centre. So far as observation can determine this the direction is towards a point in the constellation of Hercules technically called " the Apex of the Sun's way," at a probable speed of about eleven miles a second; and while thus moving along he rotates in about twenty-five days as proved by the sun-spots passing round in that time. What the extent of his orbit is cannot be conjectured. Such a question ranks with the distances of the fixed stars, very few of which are small enough to measure.

The Moon is an unfailing source of interest for telescopic observation, especially during intervening phases when the edge

or terminator is rugged ; but it is the greatest wanderer of all the heavenly bodies and requires to be followed up in its course night after night, when favourably situated. Its monthly circuit round the earth is made at the rate of thirteen degrees daily, from west to east, 2287 miles an hour, which is about half a mile a second, the slowest movement of all the heavenly bodies. It takes about an hour to go the distance of its own diameter, 2163 miles, which seems just a stately pace for so large a body, and yet it far exceeds the speed of any projectile which can be set in motion on the earth by mechanical means : a cannon ball is only about half as quick. For this reason it affords a very good idea of the amazing rate which is the standard of movement in the regions of space, corresponding with the vastness of the star sphere, in all directions. If a traveller is going in a railway train at express speed of sixty miles an hour, he has little knowledge of moving at such a rate ; but let him stand on a station platform when such a train is passing and he will start back with wonder as the train rushes past. An experience of this kind is afforded when an eclipse of the sun is being observed. The shadow of the Moon is seen a long way off sweeping over the surface of the earth like an approaching thunder cloud, and coming on at a terrific rate ; while the Moon itself, owing to its distance, is seen creeping slowly over the face of the Sun, and all is past in about two hours. If this is the slowest of celestial movements, what must the quickest be—Mercury, for instance, which is sixty times as fast ?

THE UMBRELLA STAR MAP AND THE PLANETS.

ONLY general rules can be given for observing the Planets and for identifying their positions owing to their constant motions from place to place in the sky. The outer planets can be more easily followed because of the largeness of their orbits ; Saturn, for instance, with a thirty years journey is as long as two months at a time in one region of the sky. Jupiter even, with his eleven years, remains long enough for observation when once he is well placed in the heavens; but the minor planets change their positions very much. In order to identify a planet at any particular time the circle of the ecliptic is a great help, for none of them are

ever outside the breadth of those twelve constellations which mark out the ring :—

> "The Ram, the Bull, the Heavenly Twins,
> And next the Crab, the Lion shines,
> The Virgin and the Scales.
> The Scorpion, Archer and He-goat,
> The Man who bears the Watering-Pot,
> And Fish with glittering tails."

Two of the first magnitude stars provide a good start in tracing out these signs—Aldebaran in the Bull, and Regulus in the Lion (the handle of the sickle). The ecliptic circle passes near these, and very close to Regulus, but in none of the other constellations is it so well marked. These two stars, however, are sufficient guides to the general direction of the ecliptic, and its place in the heavens. Still more definite data can be had for identifying any individual planet by finding its Right Ascension and Declination at any particular time from an Almanac, and then laying it down in actual measurement on the corresponding segment. A little practice will make this very easy and the hours and degrees will become so familiar that the eye will be able to estimate them, at least approximately.

TABLE OF SOLAR SYSTEM.

NAME.	Diameter in Miles.	Size in relation to the Earth.	Density in relation to the Earth.	Rotation on Axis.	Distance from Sun in millions of miles.	Period of Orbit.
Sun,	886,400	131000	·25	25 days.	—	—
Mercury,	3,030	·056	—	—	36	88 days.
Venus,	7,700	·92	·89	—	67	225 days.
Earth,	7,917	1·00	1·00	24 hours.	93	365¼
Moon,	2,163	0·0204	·61	—	—	1 month.
Mars,	4,230	·152	·71	24 hr. 40 m.	141	1 yr. 10½ mos.
Jupiter,	86,500	1309	·24	10 hours.	483	11 years.
Saturn,	73,000	760	·13	10 hr. 14 m.	886	30 years.
Uranus,	31,000	65	·22	—	1782	84 years.
Neptune,	35,000	85	·20	—	2791	164 years.

CHAPTER VI.

TIME—GEOGRAPHY AND ASTRONOMY.

The motions of the heavenly bodies measure out time according to the day, month and year. The Earth on its axis gives the day, the Moon in its orbit gives the month, and the Sun in its apparent circuit in the heavens gives the year; but these all require certain modifications or corrections to make them uniform for practical purposes. The day has to be brought to uniformity all the year round by calculation, and the hours, also, divided equally into twenty-four. The Sun's path, or the Earth's orbit, is an oval or ellipse, and consequently the movement is quicker at the narrower part than it is where it flattens out, according to Kepler's Law of equal areas in equal times. In order to correct this aberration a calculation is made to bring it to the true circle. Another factor in the question of mean time is the obliquity of the ecliptic, by which the sun passes a meridian before or after the same meridian cuts the equator. This again has to be equalized by calculation. Between these two a third calculation has to be made so as to get at the mean, which is called the equation of time.* These calculations are made at Greenwich Observatory every day, and signalled to the outer world by the sliding of a large ball down a pole placed on a turret; telegraph signals are also sent, and in some provincial towns and in capitals, such as Edinburgh, a gun is fired.

Thus there are three different kinds of time—Siderial or Star time, Solar or Sun time, and Greenwich or Mean time; and each has its use. Three differently constructed timepieces are used for showing the hours and minutes corresponding to each kind of time. First there is the Siderial clock which is used by astronomers for marking the exact moment of a Star crossing the Meridian (Southing) the dial of which is figured from I. to XXIV., and its pendulum beats sidereal seconds. A round

* See Equation of Time, page 106.

of this clock shows the time the earth takes to make one turn on its axis from the first point of Aries round to the same point again, viz., about four minutes less than Greenwich time. The second kind of timepiece is the Sun-dial, now almost obsolete, but in ancient times of great importance. It records the real Sun time of the place where it is erected. Its single hand or gnomon, being adjusted to the latitude, casts the shadow upon a graduated dial, and of course, can only be used when the sun is shining. The third time-keeper is the ordinary clock, with the dial divided into twelve hours, and regulated by Greenwich time.

In ancient times no inconvenience was caused in the ordinary circumstances of the people by inaccuracies, which only affected them indirectly, if they affected them at all. The months and the seasons of the year were the important things to them rather than the year itself, and the exact time to a minute was rarely required.

When the dawn of Christianity arrived this twilight-like condition began to be felt; and about the year 45 B.C. in the reign of Julius Cæsar, the discrepancies of seasons, months, and years began to be observed and corrected. That enlightened Roman Ruler by the advice of his official astronomer Sosigenes, used his universal power in promulgating an important adjustment of the calendar. The phases of the Moon, hitherto regarded as all-important, were put into a secondary place, and the year rather than the month became the unit of measurement. It was observed that when the sun reached the lower solstice on the evening of what is now the 21st of December, it remained much in the same place for the three following days; but on the morning of the next day it was found to be about a half degree higher on rising, the beginning of its yearly course in the signs. Julius Caesar would have made this day (the 25th December), the New Year's day, seeing it was so marked out by nature for that distinction, but the popular prejudice in favour of the new moon was too strong for him, and he had to wait for other eight days for the new moon which occurred on what is now the 1st of January.

In round numbers 365 days represent the year, but there are still the odd hours and minutes (5 ho. 48 min. 46 sec.) to make room for; the leap-year was invented for this purpose, so that

every fourth year should have a day more, though this is rather more than enough for a true adjustment.

This arrangement of the calendar continued till the year 1582, when the difference accumulating in twelve hundred years began to be observed, the vernal equinox happening on the 11th instead of the 21st of March, the proper day. By this time the Roman Emperors had long since disappeared, and their place was occupied by the Pope of Rome. In the year 1582 the reigning Pope, Gregory XIII., made a new adjustment to correct the error, and to prevent its recurrence in all time to come. He ordained that the 4th of October of that year should become the 15th, thus dropping out ten—not days, but numbers—and the small overplus increasing year by year should be corrected by every fourth century year having an extra day added, leap year being omitted in the other century years. The error is thus reduced almost to nil, from century to century. The correction was at once made in all Roman Catholic countries, but it was not till the year 1752 that it was adopted by the British Parliament, when the change was also made of placing the beginning of the year on the 1st January instead of the 25th of March, which had long been the custom. In Russia and all over the Greek Church, the Julian Calendar is still followed, the difference now amounting to twelve days. Both dates are however usually given whenever confusion is apprehended between the old style and the new.

The Julian Calendar did not make any change in the Era or alter the date of the current year when it was instituted. There were several eras then in use, each of them dating from some epoch-making event in the past, such as the foundation of Rome, which was the one commonly understood. The establishment of the Christian Era was not thought of until the beginning of the sixth century, when the old Roman Empire had ceased to exist. In the year 525 A.D., a Roman abbot named Dionysius made chronological researches with a view to formulating a Christian scheme of reckoning, taking the Incarnation as his starting point, calling the years previous to that, "Before Christ" (B.C.), and those coming after it "Anno Domini" (A.D.). The time was opportune for making such a change. It was taken up, slowly at first, but gradually it gained the con-

fidence of the people; yet it was two hundred years or more before it entirely superseded the older eras. The Christian Era became general in Europe about the year 800 A.D.

THE Umbrella Star-map can be made useful in schools by combining instruction in geography with elementary astronomy, the one most fitly helping the other as being closely related subjects of study. For this purpose the Star-map surface of the umbrella is reproduced upon the interior of a dome. This gives it the true shape even better than an umbrella. The handle part is also done away with and only the small projecting end on the top retained. This is used as a pivot for fixing the star-sphere in its position, elevated to the proper angle of the pole for the latitude of the British Isles. The semi-circular arch to which the dome is attached has been utilized to represent the meridian, corresponding to the brazen meridian of the celestial globe; two extensions or arms are inserted sufficiently far so as to hold an ellipse of flat wire in such a position as to represent the visible horizon in its true place on the star-surface. The points on the wire ellipse where the two arms join it are very important, as they mark out the North and South points of the meridian on the horizon. All stars that are not circumpolar will set before the north horizon point is reached; but the well known circumpolar stars such as Vega and Capella, will not set at all but will only come near to or touch the horizon and then begin to ascend. Stars not circumpolar will be seen to rise at all points on the horizon east of the meridian points already mentioned, and they will set again at all points to the west of this same line according to their degrees of Declination. By the revolving dome and the horizon ellipse a most correct understanding of the daily and annual motions of all the fixed stars on the great hollow sphere of the heavens can be obtained. The thing which is most difficult to perceive in connection with the apparent motions of the stars is the fact that the daily rotation of the Earth on its axis causes one change of their positions which is constantly repeated every twenty-four hours, while the annual motion of the earth in its orbit causes another change in their positions, which is also constantly being repeated, but at the much slower rate of only about four minutes (3′ 56″) in

the twenty-four hours—one complete revolution in the year. The dome is made to show the changes going on all the year round, by adjusting it according to the months marked on the edge; and one revolution is sufficient to show the changes in a single night. The principal constellations being learned in this practical way it becomes a very easy matter to trace out the paths of the sun, moon, and planets at any time throughout the course of the seasons.

For the geographical counterpart there is required a local map with its topographical features well defined in mile or half-mile circles, embracing the whole area of the horizon for about twenty miles around. It is spread out upon the table directly under the star-map dome, and as the dome is turned round the points of the horizon are easily identified, where the stars are seen slowly rising and setting on the ellipse horizon. This can be made more graphic if the topographical features of the surrounding landscape are modelled or sketched instead of being only drawn in plan on the map.

Still, further, the actual topographical features themselves can be taken, by observing them in the landscape on summer evenings or other occasions of stated occurrence, such as the daily walk to work or business. In the morning observe the place over which the sun has arisen, and in the evening the place towards which he is setting. Week after week as the season advances towards mid-summer, the sun will widen out in his course, rising farther towards the north-east in the morning and setting farther towards the north-west every night, until the farthest point is reached on Midsummer day, 22nd June. After that the movement is reversed, and the course gradually contracts day by day until the equinox comes in September. The sun is then rising due east at six o'clock in the morning and setting due west at six o'clock at night. When the features of the landscape are thus identified with the rising and setting of the sun in the course of the year they become very familiar, not only in an artistic sense, but also as marking a natural Right Ascension hour circle.

The study of the stars thus very properly begins with the greatest and most useful of them all—the sun itself, and next to it comes the moon. When the dark nights set in, the rising and

setting of the moon—with its phases, from the crescent streak to the full circular disc—can be observed in the same way, by associating its appearing and disappearing with the well known places on the horizon already observed in watching the Sun.

To carry this plan into the region of the stars it is better, at first, to take one particular star or conspicuous constellation, so as to fix in the mind the general principle to be afterwards applied to all. Orion is perhaps the best for this purpose, marked as it is by the three stars of the belt, known to country people as the King's Ell-wand. In the first week of December this well known group is rising in the east about six o'clock at night, and setting in the west about the same time in the morning. The subsequent movements of this group, in rising and setting, illustrate and also demonstrate the effect produced upon all the stars by the annual movement of the Earth in its orbit. For this purpose the observation must be from the same spot exactly on each occasion, and one star of the group singled out, say the bright star on the shoulder called Betelgeux. Watch this star as it rises in line with a tree or a chimney top in the near distance, and note the exact time. On the next night it will come to the same point three minutes fifty-six seconds earlier, so that in an interval of thirty days the time of passing will be $3' 56'' \times 30 =$ 1 hour 58 minutes, that is to say, the passing of Betelgeux on 30th December will be one hour fifty-eight minutes earlier than on the first of the same month.

Thus the elementary study of astronomy becomes intimately associated with the locality of the observer and assists him greatly in learning the geography of the surrounding district. The cardinal points are first ascertained marked by a hill top, spire or wood in the far distance, and then the intermediate ground in each of the four directions can be filled in, by learning the names of the places as they occur in succession towards the point of observation. The same thing is repeated by facing to the secondary points of the compass, North-East, South-East, North-West, and South-West. This will embrace a good knowledge of the whole district for twenty miles around, stretching out as far as the horizon limit.

Most people have experienced the difficulty of finding their bearings in a strange town or place, sometimes making very

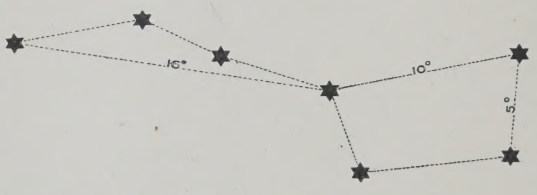
ridiculous guesses at the true directions of the cardinal points, North, South, East and West. When these have been first of all learned from nature's finger posts—the stars in their courses—there will never afterwards be any perplexity in finding the way about in any part of the globe. Even a map, being usually on a small scale, is not easily identified with the topography of the place by a stranger, without some standard of comparison which can be easily applied. In a large city like London where the labyrinth of streets is bewildering, or in lonely country districts where there are frequent intersections of roads, a pocket compass would serve this purpose. The same results, however, are obtained by knowing the positions of the sun at the principal hours of the day. He is due east at VI. in the morning, south-east at IX., south at XII., south-west at III., and due west at VI. in the evening ; and on a clear night the north and south points can always be derived from the Pole Star.

CHAPTER VII.

PRACTICAL ASTRONOMY.

ANGULAR MEASUREMENT.

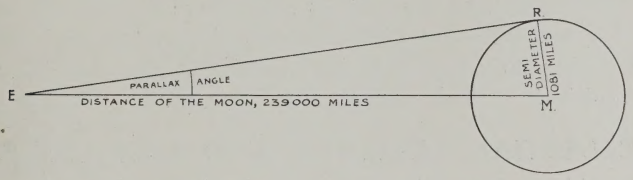
THE practical use of astronomy does not lie in the pictorial observation of the heavens, but in the more laborious work of making comparisons and deducing results. There is a *pons asinorum* in this science as in geometry, and by it the passage is made from the general knowledge of the stars, as seen by the eye, to the more particular study of their relations to each other, to the solar system, and to the earth upon which the observer stands. The first thing is to learn how to judge of size and distance by suitable units of calculation. It will not do to make estimates of these according to the idea of measurement in the mind, because each person will have a different standard to apply. One man will say the moon is a foot in diameter. another will say twenty inches, and a third will make it two feet, The same variation of opinion would appear in estimating the distance between two stars. Such a rule-of-thumb manner of reckoning will not do for practical purposes, something more definite and trustworthy is required, so that the results may be shown in accurate statements, worked out calculations, and



geometrical figures. The method employed is called "angular measurement," that is the apparent semi-diameter of a body which has a distinct disc, such as the sun, moon or planets, and the units of measurement are not feet and inches, but degrees, minutes, and seconds of arc. The relative distances of the stars in the plough afford a good illustration of what is included in

groups of degrees, and serve as a general standard for guidance in estimating other parts of the sky. A little practice will accustom the learner to become an intelligent observer in the proper way in which progress is to be made.

For measurements less than one degree, with bodies having a sensible disc such as the moon, radians are employed. The radian is that part of a circle which encloses an angle equal to its radius. It has a fixed relation to the "apparent" size of the body and its distance from the observer. It is 206265.8 seconds of arc. The application of this in determining the moon's angular distance will be understood by the following geometrical figure :—



As seen from the earth the "apparent" semi-diameter is the angle R.E.M. and the rule of computation is :—"The apparent semi-diameter of the object varies directly as the true semi-diameter, and inversely as the distance." In this case it works out as follows :—

Miles.		Miles.		Radian.		Angle.	
239000	:	1081	::	206265″	:	933″	(= ¼ degree.)

The radius of the moon being a quarter of a degree makes the moon half a degree in diameter. This half degree is a very useful unit of measurement for similar and lesser distances among the stars which are close together.

CENTRES AND CIRCLES.

"The spacious firmament on high" is far too vast to grasp as a whole. In order to learn its secrets in a profitable way, it has to be taken in detail in a systematic manner. The constellations are good for this purpose so far as they go, supplying as they do a convenient way of getting at the locality of any star. In this

respect they are like the British colonies scattered all over the world : a particular city or village may be approximately located by saying it is in New Zealand or Canada or India. In the same way any particular star is recognised as a constituent member of some constellation. Something more accurate than this, however, and of more universal application, is needed to discover the exact spot in the great star sphere where the star is situated.

Two measurements are required at right angles, *i.e.*, perpendicular to each other, so as to pass through the star at the point of their intersection, very similar to the crossing of two roads in a country district, with a finger post in the centre. This is done in the heavens above, by taking certain natural points as centres, and associating with them circles which have a direct connection with the centres. Three different sets of these are made use of, each having its advantages for special purposes, and they are distinguished by their characteristic centres.

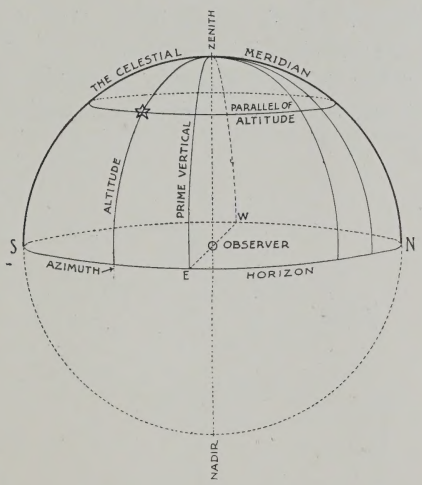
CELESTIAL LATITUDE AND LONGITUDE.

The oldest of the three methods is that which reckons by celestial latitude and longitude, having the Pole of the Ecliptic for its centre and the Ecliptic itself for its great horizontal circle, that is, the orbit of the earth, or the sun's apparent path in the heavens. This system of reckoning was of great account to the ancient astronomers, although in modern times it has chiefly an antiquarian interest. In the days of old when time was given by the sun-dial, the sun's path and its polar point went well together. Moreover, the pole of the Ecliptic has a special claim to the respect of every one who studies the stars, inasmuch as it is the only point in the heavens which does not change its position. The pole of the earth is taken for many purposes as being fixed, but it is not really so, it has a movement in a circle round this very point—the pole of the Ecliptic. It is almost imperceptibly slow, but it goes on all the same from year to year.

AZIMUTH AND ALTITUDE.

The second system of circles takes for its centre the zenith of the observer, which of course is the point directly overhead, wherever the person may be. It is determined by the plumb-line, which gives the direction of gravity, everywhere towards

the centre of the earth. The horizontal circle corresponding to this centre is the horizon. On land this is a very rough and irregular circle, being interrupted by hill and dale, wood and lake, and every possible feature of the landscape ; it is not therefore suited for correct observations on land. It is an invaluable means of reckoning at sea, because there the horizon is always a perfect circle, with the ship as the centre ; and when the weather is fine it can be relied upon with perfect confidence. The mariner can always find his whereabouts at sea by the aid of the horizon and the sextant for observing it with accuracy. Azimuth and Altitude are the two co-ordinates in this system



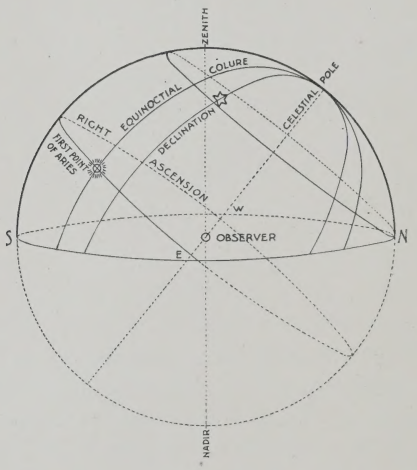
for locating the sun or a star, azimuth being the horizontal measurement and altitude the perpendicular. The meridian or south point is made the starting point, in degrees, for the one dimension, and the zenith for the other. It is called azimuth when the distance is measured from the south point to the foot of the star's vertical circle, and amplitude when the remainder of the horizon circle is taken from the star round to the south point again. In the same way for the upright measurement it is called altitude from the horizon to the star, and zenith distance from the star to the zenith.

Although this is the handiest way of proceeding at sea, it is

very inconvenient on land, because of the continual changing of altitude and azimuth, even though the zenith may be the same, and also because of the necessity of using for an artificial horizon a shallow basin of mercury. Some other means is required where all the conditions are more settled and constant.

RIGHT ASCENSION AND DECLINATION.

In the third manner of observing the place of a star, the Pole of the heavens is taken as the centre, which is simply the Pole of the Earth produced into space, and the corresponding circle is the Equator of the Earth also extended into the heavens. The figure of the planet Saturn is a good illustration of this, where the appearance of the rings is like the supposed extension, which goes by the name of the Celestial Equator, sometimes also called the Equinoctial. The starting point of measurement on this circle

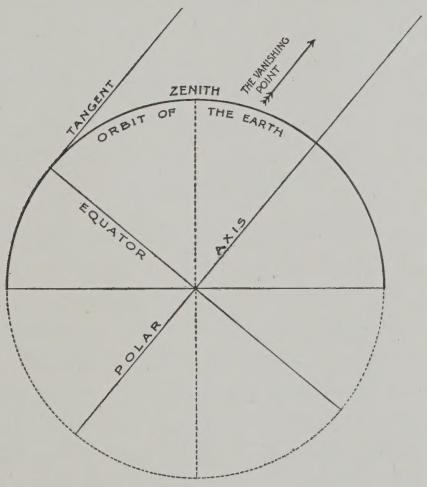


is the place of the vernal equinox, commonly called "the First Point of Aries." It is the place where the two great circles, the Equinoctial and the Ecliptic, intersect each other corresponding to the sun's position at the vernal equinox. From this point the distance is reckoned in time—hours, minutes, and seconds. The standard Meridian, which passes through

Greenwich Observatory, is the mark on the earth corresponding to this, and when the first point of Aries crosses that Meridian the time begins to count. Every star in succession which crosses has its own fixed time for doing so; this is called its Right Ascension, and it is set down in the columns of the Nautical Almanac. The same time applies to every other station, because the stars all keep the same relation to the first point of Aries everywhere. Declination is measured in degrees from the equinoctial to the pole.

THE VANISHING POINT.

The questions may be asked; What is the circumference of these circles which embrace the whole heavens, and what is the value of one degree in miles, or one hour of Right Ascension? The answer is, that it is not possible or necessary to interpose any limitations of this kind, for although they are not infinite



in the absolute sense, they are so in the mathematical sense. Observation and calculation cannot go beyond a certain assumed limit, and this *Ultima Thule* is called the "Vanishing Point." All parallel lines which can be supposed as drawn from the earth, or even from any part of the solar system, appear to converge into a point in the depth of space, so that the sun as seen from

the nearest fixed star would only appear as a point like any other of the stars, and the definition of a point is, that " it has position but no magnitude." Not one of the fixed stars can be seen as a disc with the greatest magnifying power of the largest telescopes, or even by the photographic camera ; a tiny point of light, bright or dull, is all that can be made out, although evidence is attainable that they are all as large as the sun, and many of them much larger.

The " vanishing point " is well illustrated by the parallel lines of a railway track. Standing in the six-foot-way with a couple of rails on either side, and looking along a straight part of the line for over a mile in advance the four lines will be seen gradually converging towards each other, until in the far distance they appear to meet. If a mile or two is sufficient to effect this on the earth, how much more will the depth of space which is unfathomable account for the same process of drawing into a point all the lines of astronomical observation. Of course lines that are parallel can never meet or get any nearer each other, no matter how they may be prolonged, but they appear in the line of sight to do so, and that is sufficient to account for " the vanishing point."

LATITUDE.

The first practical application of astronomy is to determine the latitude of the place where the observer is located. If there were a star situated exactly at the pole, its elevation taken in degrees would give the observer's latitude, because it is one of the fundamental relations in astronomy that "*the altitude of the Pole is the latitude of the observer.*" If he were standing at the North Pole the Pole Star would be right overhead, and if he were at the Equator it would be on his horizon ; between these two extremes it would be seen high or low in the sky according to his latitude.

The Pole Star is near the Pole but not exactly at it, and not nearer than $1\frac{1}{4}°$. How then is the place of the Pole to be determined ? The most approved method is to observe with a suitable instrument a particular circumpolar star when it is crossing the meridian above the Pole, and again twelve hours later when it

crosses under the Pole the mean of the two angles of distance would be the place of the Pole, and the true latitude. This is a common experiment practised in observatories. It is done by the instrument called the "Meridian Circle," which is a large telescope moving only up and down on the meridian, and fitted with a large graduated circle of degrees. The markings are very accurately divided down to seconds of arc and decimal fractions of seconds requiring a microscope to read them, so that great exactness is obtained by the use of this instrument. In observations of this kind allowance has to be made for the refraction of the atmosphere. When light passes from a rarer to a denser medium, it is bent out of the straight, and this is why a stick plunged partly in water appears to be bent, though in the opposite direction to the rays of light. The amount of the refraction varies with the density of the atmosphere which becomes rarer as it ascends. At the horizon a ray of light is bent as much as 35 minutes of arc, so that the sun or moon in rising appear above the horizon, when in reality they are still below it. The bending of the rays of light lessens as the height increases, until a star right overhead would have no refraction at all. Because of these variations this is one of the most troublesome adjustments to make in observing a heavenly body.

LONGITUDE.

To find the longitude of a place on the earth or the sea is one of the most important uses of astronomy. It was for this purpose chiefly that such institutions as observatories and nautical almanacs were at first established. Longitude is one of the series of data required for determining the whereabouts of a ship, so that the voyagers might always know where they were on the wide ocean. As latitude gives the position north and south, so longitude gives the distance east and west, and the point of intersection is the spot where the vessel is at the time. Latitude therefore has its relation to the Pole and the equator, while Longitude relates to the equator as it circles around the globe. This circle is divided into hours, which are marked off by meridians, twenty-four meridians of one hour's distance between each,

which is the same as fifteen degrees of arc. The standard meridian is the south point at Greenwich Observatory, and the "transit instrument" there moves up and down on this line. The twenty-four hours begin to count from there, "mean time" being calculated every day by correct allowances for the ellipticity of the earth's orbit, and the obliquity of the sun's path in the heavens—the Ecliptic. The turning of the earth on its axis is precise and uniform from day to day, making a complete revolution in twenty-four hours, the longitude therefore of any place on the earth is the difference between the local time of the place and Greenwich mean time—the amount by which noon at Greenwich is earlier or later than noon at the station of the observer. The difference has only to be made known by comparing notes in some reliable form of communication such as the telegraph where that is practicable.

In the case of a ship at sea some other means than this must be found, and the best way as yet discovered is to carry Greenwich time on board by the use of the chronometer. This is just a very carefully constructed watch, usually with two complete sets of works and two independent dials, the one checking the other. Before setting out on the voyage it is regulated by comparison with a standard clock, which is itself kept right by the transit instrument observations from day to day. Two or three chronometers are usually carried on every ship as a safeguard for greater accuracy, so that if one should go wrong there would be two to testify against it, and their version of Greenwich time would be taken as the correct one.

A SHIP AT SEA.

With the chronometer on board showing Greenwich time the local time of the place has to be found so as to compare the two together to find the longitude. This is done by means of the sextant, a useful and portable instrument invented by an American called Gregory in 1730. The observation is made when the sun is due east or due west, and by it the sun's "hour angle" is obtained, that is the solar time, and from this the local mean time can be calculated. The chronometer then comes in with the Greenwich "mean time" and the difference between the two

is the longitude. The latitude is obtained by observing with the sextant the sun's maximum altitude, which occurs when he is crossing the meridian—the south point of the place at 12 o'clock. Corrections are made, in this first result, for the *semi-diameter* of the sun, the *dip of the horizon*, *refraction* and *parallax*, and then the true altitude of the sun's centre is found, and this deducted from 90° gives the zenith distance. The nautical almanac gives the sun's declination for Greenwich for the same day, and from this the exact declination at the moment of observation can be got. The latitude is the declination plus the zenith distance, and with care and a good sextant the whereabouts of the ship can be determined to within half a minute of arc, which is about half a mile.

THE STAR SPHERE.

The idea of the ancients was that the earth was fixed in the centre of a vaulted sphere and that all the stars and planets revolved around it, the stars in a regular way and keeping rank, and the planets wandering in an erratic way. Hipparchus a hundred and twenty years B.C. taught this theory, and Ptolemy in the second century of the Christian Era still continued it. The Arabs in their palmy days had the same way of explaining these movements, and the Christian nations for many centuries made no advance upon it. Many of the problems to this day are just the same whether the movements are attributed to the stars or to the earth. Without knowing anything at all about the earth and its motions these ancient astronomers were able to learn much about the works of creation in the starry firmament. They learned in the first place to observe the stars which the sun passed through, or seemed to them to pass through, in its yearly course and to group them into the twelve constellations of the Zodiac, and many others were added to these in different parts of the sky. The stars composing them were singled out by name and night after night watched with an attention which amounted to a religious vigil. The natural assumption which they made of the earth being the fixed centre of all the movements did not interfere in the least with the conclusions they drew, because they were unconsciously dealing with distances beyond all human

calculation. Even yet the apparent motions of the heavenly bodies are the basis of many calculations. In dealing with these it is often convenient to speak of the stars moving just as they appear to do : the apparent motions are those which arrest the attention, and it is not necessary always to dispel the illusion.

Just before the Reformation, about the year 1500 A.D., Copernicus advanced the proposition that the earth moved, and that the sun was the fixed centre. This was a great discovery although it had not yet been proved ; it was only claimed for the theory that all the other apparent movements were better explained by it than by any other assumption. From this new beginning much advance has been made in the knowledge of the earth itself, its spherical form, its diurnal rotation, its yearly revolution round the sun and many other important data. Remarkable precision has also been attained in the observation, measurement, and calculation, of the composition, distances and periods of many of the stars.

DIURNAL MOTION.

The motion of the earth on its axis is the first real cause of change in the positions of the stars. Turning round once in twenty-four hours it brings them into view every night in nearly the same places. There would be little difficulty in identifying these places and keeping hold of them night after night if there were no other causes of interference to displace them, because they would always rise and set at the same time and in the same place. About the autumn equinox in the month of September, when the evenings are beginning to get dark, looking northward about eight o'clock the Plough is seen sloping downwards in the west, and the opposite constellation Cassiopeia is high up in the eastern sky. Auriga, with its principal star Capella, is intermediate between these two, and directly opposite is the Lyre, with Vega shining in brilliant lustre. These four constellations are very useful to know as they occupy the four quarters of the northern heavens, and they never set below the horizon in the latitude of the British Isles.

ORBITAL MOTION.

If the daily rotation of the earth were the sole cause of star movement the circumpolar constellations would be nearly all that are ever seen, and those in the daylight portions of the sky would never be seen at all. This is obviated by the motion of the earth in its orbit going round the whole circuit of the heavens and, in the course of the year, bringing into view many other stars. It might be compared to a person in a picture gallery passing around and observing every picture in turn, instead of simply reclining in the same position in the centre of the room and looking in one direction only. Comparatively speaking the movement is slow, for although the earth travels the enormous distance of a million and a half of miles every twenty-four hours, it only gains on the stars three minutes fifty-six seconds each turn. At this rate there is always a little more, and a little more of the starry sphere brought into view night after night, until the whole round of the year is made.

The diagram of North Circumpolar Stars on page 17 affords a good idea of how these changes are brought about and how they are to be reckoned for and formulated. There are two circles of hour figures. The innermost of these represents the twelve hours of an ordinary clock repeated for day and night and set to Greenwich time. The other and outermost circle of figures represents the hours on the dial of the siderial clock running from I. to XXIV. The siderial time requires to be kept in this way so as to denote the Right Ascension of the stars by going round in one turn the complete range of the twenty-four hours constituting one complete stellar day. Noon by this process of reckoning is not when the sun crosses the meridian, but when the first point of Aries does so. Accordingly this point is marked with the sign of the ram's horns on the outside of the circles, at the place of the vernal equinox on the twenty-first of March. Every day after that siderial noon comes 3′ 56″ sooner as the earth goes on its annual journey to meet the stars. Those minutes and seconds amount to an hour in a fortnight which is two hours a month and twenty-four hours in the year, that is a whole day more than the $365\frac{1}{4}$ of the ordinary year. A day is gained by the earth in its yearly orbit by the accumulation of

the three minutes fifty-six seconds of daily difference. It is a very similar thing to this that happens in circumnavigating the globe. If a vessel takes an easterly course, that is, going to meet the sun, a day is gained on the whole round of the voyage ; and if a westerly course is steered, there is a day lost by lagging behind the sun. The rule for adjusting this is, for sailors going east, to drop one day out of their log when they come to the meridian of 180 degrees of longitude, directly opposite Greenwich ; and for sailors going west a day is added by going over the previous one again when they reach this spot. It is the very same thing which is done by the earth in its yearly circuit among the stars, it passes the first point of Aries once more than three hundred and sixty-five times.

THE EQUATION OF TIME.

There are two principal causes of irregularity on the part of the earth in moving round its orbit, which make the natural days of different length, and consequently exceedingly inconvenient for practical purposes. One of these is because the orbit is not a true circle but an ellipse, and according to a law discovered by Kepler the motion is quicker at the narrower part near the sun, thus causing unequal days. The other principal cause is the obliquity of the ecliptic, by which the sun crosses a particular meridian before or after the same meridian cuts the equator, again causing unequal days. The equation of time is the adjustment of these to bring them into uniformity. It is done by imagining a fictitious sun which is supposed to go round a perfectly circular orbit on a perfectly level ecliptic. This calculation is made every day at Greenwich Observatory and signalled at one o'clock by telegraph all over the country.

The siderial clock with its pendulum beating seconds and its dial showing hours and minutes, gives the position of any star as it crosses the meridian of the place where the clock is situated. It shows noon exactly when "the first point of Aries" makes the transit, and every star which follows in long procession the whole round of day and night has its time noted when it comes to this south point. Its distance from the first point of Aries is reckoned in time, and this is called its Right Ascension. In order to know how high or low it is on the hour circle its declina-

tion north or south of the celestial equator is measured in degrees. There is no difference in kind between R.A. and Decl. Both are angles, but R.A. can be conveniently measured in time through the earth's rotation at 15° an hour. Between these two the position of any star can be accurately laid down in diagram form.

As a practical illustration of this let a circle be drawn on the black board at 45° radius, which will include all the circumpolar stars in the northern sky. Divide this circle into twenty-four hours with their corresponding minutes. Read off from a star catalogue the Right Ascensions and declinations of the seven principal stars in the Plough, and mark them with chalk in their true places. Take another constellation Cassiopeia, situated directly opposite the Plough, and mark off the five chief stars in the same way. Put in the bright star Capella to represent the constellation of Auriga, and finally take Vega, the characteristic star of the Lyre. A large cross of equal arms is thus depicted in the sky with a well known constellation in each of its arms and the Pole Star at the point of intersection. The Right Ascension clock-face time can be roughly estimated by the positions occupied by these, as they go round. Cassiopeia is directly above the Pole at siderial noon, and the other three are then relatively placed for the quarters VI., XII. and XVIII. Owing to the 3′ 56″ displacement every day siderial noon occurs at all times of the day and night, but the calculation is not a very difficult one to convert it into Greenwich time. This is rarely required, however, for general observation, as the positions can be learned from a map sufficiently accurately to find the place of the star, and with some practice the distances can be approximately estimated.

The middle circle of the diagram (p. 17) has the months marked upon it, beginning with the month of March, the twenty-first day of which is put at the sign of Aries, the ram's horns. At one time the civil year was reckoned from this month because of its equinoctial importance; September, October, November and December were then the seventh, eighth, ninth and tenth months respectively, as their names indicate. When the change was made in 1782 from the old style to the new, the first of January became New Year's Day, and these four months are now the ninth, tenth, eleventh and twelfth of the year.

THE PRECESSION OF THE EQUINOX.

Besides the diurnal and the yearly motions of the earth there is a third principal cause of apparent star motion. It is called the precession of the equinox. It is a kind of swaying like the spinning of a top when it is slowing down so that the pole of the earth is made to describe a circle in the heavens. The extra bulk of matter at the equator, together with the flattening at the poles, is the cause of it. The earth is balanced in space by the sun's attraction and its own momentum, just as if it were floating in some yielding liquid like water, but without the friction of being tugged along. A slowly swinging motion is the result, which causes the pole of the earth to make a complete revolution in the very long period of 25,800 years. This movement was observed as far back as the second century B.C. by Hipparchus. He found by observation that the year was longer by twenty minutes when reckoned by the constellations than when reckoned by the equinoxes. He did not know the cause of this, but he noted the fact and called it the precession of the equinox, because it was in advance of the stars nearly one minute of arc, year after year. It is very slow and not of much account in identifying the stars, but it has to be reckoned with in compiling their catalogues, because it affects their right ascensions and declinations, these being determined in relation to the first point of Aries and the Vernal equinox.

HISTORICAL.

Some interesting historical events have been discovered from the effects of the precession movement away far back in ancient times. The age of the great pyramid of Egypt has been determined by this peculiar astronomical circumstance, because of its effect in displacing the Pole Star from time to time, and even discarding it altogether and taking another. The complete circle described by the pole may be drawn upon a star map, and the different stars having their positions on or near it can be marked. The time also can be calculated, backwards or forwards, when one or other of these has been, or will become, the Pole Star. The

great pyramid has an entrance well up in the northern side. It is a deep slanting tunnel reaching down into the interior. Looking up through such an elongated aperture and surrounded with darkness on every side, any star coming into its field of view would be seen even in daylight. Counting backward for 4,700 years the Pole Star of that time was Thuban in the Dragon, and this tube in the Pyramid pointed nearly exactly to it for a whole century or more. This star has thus a special historical interest attaching to it and should be known by every one. It is the third from the end of the Dragon's tail, almost in line with the two stars opposite the pointers of the Plough. This shows in a very graphic way how the precessional movement has gone in the course of nearly five thousand years, one fifth part of the whole circle.

Another interesting historical circumstance of the same kind shows how the precession affected the temples of these ancient times in Chaldea and Egypt. They were enormous structures, as many of their ruins show, and they were always built in positions so as to point to the rising or setting of some particular star which was watched and honoured like a medieval saint. The temples were oriented so that the long vista from the innermost shrine to the outermost pair of pylons at the entrance—sometimes a quarter of a mile away—would act in the same way as the long tube of the Pyramid by intercepting some particular star. By the precessional movement the star would gradually be lost to view in this particular way, though it would take a long time to pass entirely away from such a strange architectural telescope. Instances have been found, however, in which the favourite star has been followed up and recovered after having been lost sight of, by building another temple beside the more ancient one, but at a different angle. Future generations were in this way able to go on as before, until in the course of time they too would be thrown out of touch with their favourite starry symbol of divinity.

The study of the stars has thus the recommendation of antiquity to stimulate the zeal of the modern student and awaken renewed interest in astronomy. No doubt cloudy skies and uncertain climate have a discouraging effect in trying to follow up the subject in a practical way. A great deal of useful

preliminary work can be done within doors without directly looking at the stars at all, and when the opportunity of a clear, starry night does occur it will be used to better purpose because of previous study.

Leaving prehistorical times and coming to the actual records of authentic history, a good starting point is the adoption of the METONIC CYCLE in Athens by public ceremonial on 16th July, B.C. 433, after which it was followed by all the cities and colonies of Greece. The Greek sage Meton made calculations which proved that 235 lunar months were equal to 19 solar years, there being only a few hours of difference. The consequence of this is that the phases of the moon repeat themselves, each corresponding year of the cycle, on exactly the same days of the month; an old almanac of nineteen years ago is quite up to date in this respect. In order to find which year in the cycle corresponds with the current year, add 1 and divide by 19. The remainder is called the *golden number*, because it was originally written in gold characters to distinguish it from the other figures in the calendar. It is still used for determining the date of Easter, which is the Sunday after the full moon coming after the vernal equinox.

The JULIAN YEAR was adopted on 1st January, B.C. 46, which was the 708th year from the foundation of Rome. The previous year was called "the last year of confusion," because it was extended to 445 days, in order to take up all the arrears which had accumulated, and enable a new beginning to be made.

The idea of the ancients was that the earth is the centre of the universe, and that sun, moon, planets, and stars revolve around it. This put early astronomers to great ingenuity to account for the irregular movements of these bodies. HIPPARCHUS, about the year 120 B.C., discovered that the solstices and the equinoxes do not divide the year into four equal parts, but that the sun is 187 days north of the ecliptic, and only 178 days in the southern portion. This did not agree with circular motion, and to imagine an ellipse was to do violence to all received opinions of stellar revolution. He was consequently driven to the supposition that the earth was not exactly in the centre, but that the star sphere revolved in an eccentric manner around it. The varying distances and periods

of the planets were accounted for in this way, though there were still discrepancies.

Three hundred years later PTOLEMY (A.D. 140) came nearer to exactitude by a more complicated theory. He imagined that the planets moved in an epicycle, the centre of which also moved, but in a larger circle around the earth. He still had to retain the eccentric character of these circles.

In the long interval of the Middle Ages, astronomy made little progress, and such as it did make must be attributed to ARABIAN influence. Their conquests in the east of Europe made them heirs to much of the ancient Grecian culture, and some eminent astronomers appeared among them. One of the most lasting benefits derived from this source is the names of the stars. There are about 120 stars to which separate names have been given, and these are mostly of Arabic derivation.

In the beginning of the sixteenth century COPERNICUS made a great step in advance by assuming that the stars were really fixed and motionless in the remotest bounds of the universe. The sun, he affirmed, was the fixed centre of the whole, the earth and the planets revolving around it. He had no proof whatever to offer in support of the theory, except that it accounted better than the older notions for the movements of the planetary bodies, and the diurnal revolution of the heavens; but, withal, he still had to retain the eccentric circles to account for the aberrations of the planets.

Early in the 17th century a decided step was taken to get over the old prejudice that the stars could only go in circles. KEPLER, with the help of TICHO BRAHE'S recorded observations and his own study of Mars, came to the conclusion that an elliptical orbit only could account for the movements which the measurements revealed. Moreover, he found that the motion was not uniform, but varied in different parts of the orbit. Still further, he saw that there was a fixed proportion between the period of revolution and the distance from the sun. These three discoveries are called KEPLER'S LAWS.

1. The orbit of each planet is an ellipse, with the sun in one of the foci.

2. The radius vector—the connecting line—sweeps over equal areas in equal times, shortening or lengthening according to the bend of the curve.

3. The cube of the distance from the sun is as the square of the period of revolution.

The discovery of the law of gravitation by Sir ISAAC NEWTON confirmed the previous observations of KEPLER, and proved that the motions could not be otherwise than as he had formulated them; they were according to inherent and invariable properties possessed by ponderous bodies in relation to each other.

The invention of the telescope by GALILEO in 1610 was the beginning of a new departure in the study of the stars. With an instrument of his own construction, of 32 times magnifying power, he discovered Jupiter's moons, the sun spots, the phases of Venus, and the inequalities on the moon's surface. He almost got as far as Saturn's rings, but his telescope had not power enough to make them out. It was evident there were appendages of some sort, but he supposed them to be companion stars in close proximity to the planet.

Fifty years later HUYGENS (1655), with an improved telescope, made the full discovery of an encircling ring, though its composite character was not determined until much later. This astronomer added an important accessory to practical astronomy by the invention of the pendulum clock.

The invention of Logarithms by NAPIER about 1600, provided a useful means of abridging abstruse calculations, inseparable from astronomical observations, by the use of addition and subtraction instead of multiplication and division.

The establishment of GREENWICH OBSERVATORY in 1676 brought the study of astronomy into the practical affairs of life, by regulating time on land, and determining longitude at sea. Many other useful purposes have been served by this institution, and some of the astronomers royal have been foremost in observation and discovery. HALLEY (1681), who was the second to hold this appointment, is associated with the famous comet which bears his name. He discovered that it moved in an elliptical orbit, in a period of 76 years. It has twice returned, according to prediction, since it was first discovered, and is expected again in 1910. The proper motions of stars were first ascertained by this astronomer. In 1718 he found that since the time of Hipparchus, B.C. 120, Arcturus had

moved southward nearly one degree, and Sirius had made a journey of half a degree from the place it occupied at the beginning of the Christian era.

In the beginning of the 19th century BODE'S LAW was formulated, though it is something of a misnomer to call it a law, since it is only approximately correct; yet it has a special interest as suggesting something which may be cleared up by subsequent discovery. It shows some relation in the distances of the planets from each other and from the sun. This law points out a geometrical progression in these distances, which comes very near the actual measurements.

The numbers 0, 3, 6, 12, 24, etc., are first set down as representing the planets from Mercury to Neptune; then the number 4 is added to each of them, the sum of these respectively, divided by 10, brings out a remarkably near approximation to the real distances, expressed in astronomical units (93,000,000 miles). The assumed law, however, breaks down at Neptune, the outermost planet, and it is not strikingly near for Mercury, the innermost, which should be represented by $1\frac{1}{2}$ instead of zero. As an offset to these discrepancies it comes out well with the asteroids. It was the application of this law which led to the discovery of the first asteroid, Ceres, on 1st January, 1801. It was roughly located by Bode's law, and then searched for with the telescope until it was found.

BODE'S LAW.

	Mercury.	Venus.	Earth.	Mars.	Ceres.	Jupiter.	Saturn.	Uranus.	Neptune.
	0	3	6	12	24	48	96	192	384
	4	4	4	4	4	4	4	4	4
Bode,	·4	·7	1·0	1·6	2·8	5·2	10·0	19·6	38·8
Distance,	·3	·7	1·	1·5	2·6	5·2	9·5	19·1	30.

CHAPTER VIII.

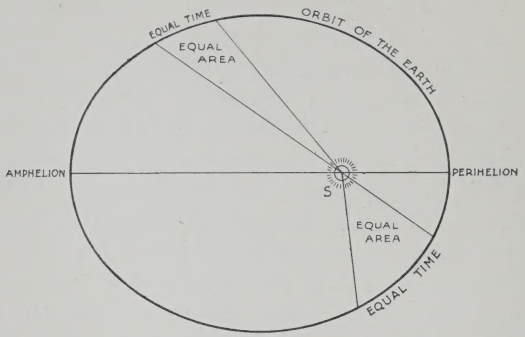
SCOUTING.

Scouts are the eyes and ears of the Intelligence Department, to obtain at first hand all that can be learned by personal vigilance, inquiry, and investigation. Not a mass of undigested facts noted down either mentally or in a book, nor a pedantic exaggeration of trivial things, however interesting these may have been at the time, but original observations deduced from what has been ascertained are required. A good scout should aim at generalising the important points into a common-sense narrative, showing their bearing upon the object in view. The methods to be employed will depend very largely upon personal shrewdness and invention; and the means to be employed for the application of these must be of the simplest and most portable kind. When the country which is being scouted is well known, either by maps, diagrams, views from heights, or personal knowledge otherwise acquired, there will be little difficulty in finding the way about even for miles around. The method will then be largely by what sailors call dead-reckoning, observing the outstanding landmarks and noting the time in passing these on the way. A good watch is of importance, whether it is of intrinsic value in itself or not, if it keep correct time that is the principal thing. It not only assists materially in terrestrial movements of an extended sort, but it also puts the owner into touch with a number of celestial phenomena, useful for reckoning where the country is strange and its landmarks unknown and misleading.

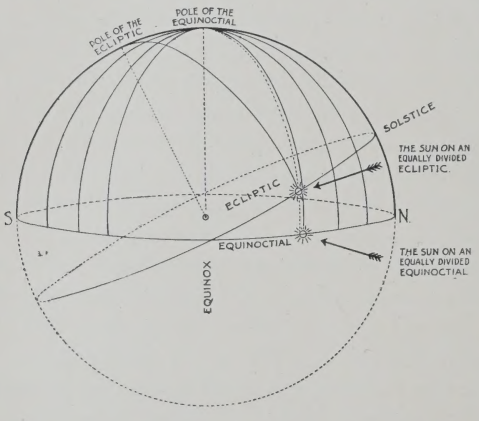
The first lesson on the WATCH is to know where its time comes from. This introduces several questions in astronomy, the knowledge of which is very useful for purposes of scouting by night when the stars are out. If a general knowledge of the heavenly bodies is carried about, it will not matter so much although the country be unknown, because the stars are always the same, if their movements have been learned. A familiar companionship with the stars will go far to counterbalance the feeling of loneliness

which is depressing in a strange place. The hours on the face of the watch are arranged according to the revolution of the earth on its axis, the double twelve being a time-honoured mode of differentiating between the duration of the day and the night. In olden times "the creeping shadow passed over the antique dial stone" silently and in direct correspondence with the motions of the earth in relation to the sun. In the alternating seasons of the year the shadow was elongated or shortened, but the ancients had little idea of the causes of these changes, and no means whatever of detecting the finer variations in the length of the day during the course of the year. Up to a comparatively recent period it was firmly held that the movements of the earth and the planets must be in circular orbits, as the circle was the only perfect curve; and these heavenly bodies could only go according to this idea of perfection. It has been found that so far from this being the case it is quite the other way, and that there is not such a thing in the whole universe as a perefctly circular orbit. The planets, the comets, the Nebulæ, and even a few fixed stars whose orbits have been observed, all move in elliptical curves, not two of which are exactly alike in size and shape. The times of their revolutions, therefore, are all different, and if that be called a year, then there are many different lengths of year. The ellipse may be accounted for, by the pull of the sun upon the planets, carrying them all round in his vast orbit; together with the initial velocity and direction of their own proper motions. The orbit of the earth has this peculiarity of ellipticity in common with the rest, and the consequence of it is a variation in the length of the divisions of time, as the earth proceeds on its yearly course. No variation has ever been detected in the rotation of the earth on its axis. What is called twenty-four hours is always the same in respect of the earth's rotation, but the speed of the earth in its orbit varies, and that makes a difference. The earth's speed is greatest at perihelion, because of the velocity gained by falling towards the sun, and it is least when farthest from the sun as the speed of a cricket ball is least at the highest point of its flight. This fact was discovered by Kepler and demonstrated by Newton, and called the law of equal areas in equal times.

It will be readily seen by the diagram that the areas are of different shapes though containing the same superficies, but the portion of the orbit gone over is much greater at the one place than at the other.



The second cause of variation is due to the obliquity of the ecliptic. This is not so easy to understand without a demonstration on the celestial globe, but it is delineated in the accompanying diagram.



The equal divisions into meridians on the equinoctial do not coincide with equal divisions on the ecliptic, because they are not parallel planes, but the one is inclined to the other twenty-three and a half degrees. The consequence of this is that the sun reaches the meridian crossing the ecliptic at different times

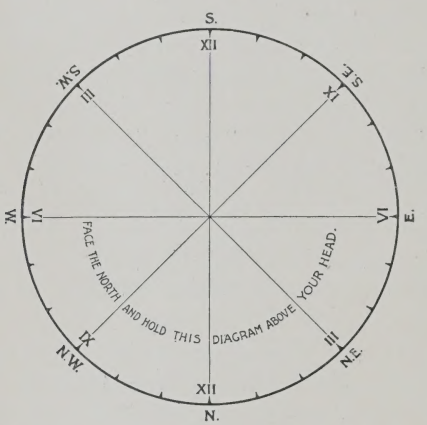
from the same meridian crossing the equinoctial. These variations are greatest at the intermediate places, and at the solstices and equinoxes the two circles agree. The sun dial is faster than the clock when the sun is half way between the vernal equinox and the summer solstice, as shown on the diagram, and in each quadrant of the orbit there is a similar variation, at one time minus and at the other plus.

These two differences, due to the ellipticity of the orbit and the obliquity of the ecliptic, have to be added or subtracted from sun time to get "mean time." Accurate observations are made at the premier observatory, so that from one o'clock to one o'clock each day, throughout the whole year, the proper length of the twenty-four hours is given. A fictitious sun is imagined to start with the real sun, and to complete the round in the same time, but in the equator instead of the ecliptic and at a uniform rate equal to the average or mean rate of the sun's motion throughout the year This "mean" sun having no existence has no shadow, and the difference of time cannot be shown on the sun-dial. It is in advance of the shadow on 11th February, 14 minutes 31 seconds; behind it on 14th May, 3 minutes 51 seconds. Again in advance on 16th July, 6 minutes 31 seconds, and on 3rd November it is behind as much as 16 minutes 19 seconds.

The CARDINAL and intermediate points of the compass can be ascertained in daylight, by the position of the sun in the heavens, if the scout's watch is keeping good time. At the time of the equinoxes the sun rises due east at six o'clock in the morning, and sets due west at six o'clock in the evening. At all other times of the year he is at these same places at the same hours, although higher up in the sky in the summer half of the year. He is always at the south point at noon, and in the mid-summer months he rises very early and sets very late. This adds two intermediate points, north-east at three in the morning and north-west at nine in the evening in very high latitudes. The only remaining point is the north, which can be got from the pole star when darkness sets in. The moon lends itself by night as the sun does by day for obtaining guidance, but it has its own peculiarities of interpretation. Only general indications can be given of its movements because they are so

variable. Particular observation is the best way to learn how to know, at all times, THE AGE OF THE MOON.

The path of the moon is practically the same as the sun—that is, on the ecliptic. It deviates from this circle only five degrees on each side in the course of a cycle of nineteen years. While the sun takes a whole year to make the journey round, the moon does it in a month; and yet the moon is said to lag behind the sun, and this is actually the appearance it has as seen from the earth. At new moon the three bodies are in a line, with the moon in the middle; at full moon the three bodies are in a line, with the earth in the middle. When the moon in its lagging gets between the sun and the earth, the dark side of its disc is



towards us and it cannot be seen, and is then known as new moon. One whole turn of the earth in twenty-four hours thereafter, shows the moon to have gone thirteen degrees eastward, and a small view of its illuminated surface can be seen from the earth. Again another twenty-four hours, and another thirteen degrees away from the sun, and still more of the bright side is seen. When this comes to three and a half days, the moon is said to be in its first octant or eighth part. When it has doubled this to seven days, it is the age of half moon; and this again doubled to fourteen days, brings the age of full moon. All this time of growing old (waxing) the increase of size is on the dark side—that which is farthest from the sun—and the moon sets before midnight. Now begins the diminishing or

waning, and as one half of the journey round is completed, the illuminated side begins to turn away and wears out gradually, the opposite way it comes in. As the full moon must always be opposite to the sun, that phase of it can only begin when the moon is rising and the sun setting. The moon has then the full sweep of the heavens the whole night through, but the lagging is still going on. The thirteen degrees of distance is equal to fifty-one minutes of time, in which it is later in rising every night, so that after the full, the moonlight is mostly thrown into midnight and the early morning.

Another peculiarity to be observed in the moon's varying position in the sky, is its different altitudes in the course of the year. When in the gibbous phase (hunch-backed) and coming to the full, it is opposite the sun in the ecliptic path; consequently when the sun is low in the heavens, as in the winter season, the moon is correspondingly high. This is what makes the moonlight nights so much brighter in winter than at other times in the year when—

"The high moon sails upon her beauteous way."

In the late autumn—September and October—the phenomena of the harvest and the hunter's moons occur. At this time of the year the moon rises nearly full at sunset, and almost at the same time for several nights in succession, the lagging being partly neutralized by other causes. Its ecliptic path is low, being about the time of the equinox. Instead of rising boldly up almost at right angles with the horizon as in winter, it skirts the horizon at a low angle, and is in consequence much magnified in size, as seen through the density of the atmosphere, creeping along the lower part of the sky. It is also of a deeper tinge of colour owing to the same cause.

Principal among all the guiding lights at night is the POLE STAR. All the others change with the rotating and revolving earth, but this one keeps its place day and night. It is not very conspicuous, being only of the second magnitude, but its position is important as giving the direction of north. It is readily found by following the line of "the pointers"—the two right hand stars in the plough. From this the other points of the compass can be easily deduced. A person standing looking up to the Pole Star and stretching his arms outwards, would be like a

finger post at cross-roads. Directly in front of him would be north, behind him would be the south point or meridian, his right hand would be pointing due east, and his left hand due west.

In the case of the Pole Star being obscured by clouds, there is still a possibility of picking up the north if any constellation, or portion of a constellation, or prominent star be in view, sufficient to be identified. Although the stars are continually changing their positions in relation to the observer, they do so in accordance with fixed principles and well known causes, in the course of the night and in the course of the year. The same star or constellation will always be found in the same place on the same night and hour year after year. If this position can be ascertained at the particular time wanted, the cardinal points can be deduced from it. This would, in ordinary circumstances, involve a very complete and intimate knowledge of the stars in their courses, which even few astronomers have at their finger-ends. By the use of the Umbrella Star Map a novice can arrive at a sound conclusion. This chart can be set to show the state of the sky at any hour in the night and any night in the year, by following a few simple rules of adjustment given on page 11. It is not to be expected that a scout would carry an umbrella with him when on duty—that would be unprofessional—but it should be part of his equipment for reference, to be consulted beforehand when any difficulty of this kind is anticipated. In reconoitring for a night march the stars can lend assistance to give the direction, after the manner of a lighthouse in steering a ship; but whereas the mariner's guiding light is steady, the scout's starry beacon is on the move. Allowance has to be made for the rotation of the earth on its axis, which is at the rate of fifteen degrees for an hour. A good measuring line for this space is the plough handle, its apparent length in the sky being rather more than fifteen degrees. If the march be nine miles, that would be a three hours' journey, or, if the country were difficult, four hours. Several stars would require to be taken in succession as the one went off the track to the right, the next would be coming on to it from the left. It is generally possible to get a series of stars nearly equi-distant from each other, at intervals of about fifteen degrees, although perhaps not on the same line of declination. Before setting out, a good

look would require to be taken at the Umbrella Star Map (remembering the rules of adjustment at page 11), so as to get hold of the proper stars and fix them in the mind. A little sketch of that part of the sky could be made to aid the memory, roughly setting forth the stars required, in their relative places to each other. If the time of the year were in the middle of September, the hour of starting half-past eight at night, and the route due south, then the star Altair would serve as the first in the series (Segment VII., page 56). It is easily recognised as the centre of a group of three, like Orion's belt. About fifteen degrees east and a little higher up is the small constellation Delphinus—the Dolphin. The third point could be made at Enif, an advanced star of Pegasus (see Segment VIII., page 62), and the fourth, Markab, at the lower right hand corner of the great square. If a fifth were required Algenib, across the square, would do very well.

Having found the "bearings" on the earth by means of the stars, it may sometimes be required to FIND OUT A STAR in the heavens from the observer's position on the earth. There are several ways of doing this. The first and most common way is by Right Ascension and Declination (page 13). In an observatory all that is required for this is to set the transit instrument (page 60) to the proper declination angle, and wait until the star comes into the field, which it will do at the exact moment given in the catalogue; but this can only be done in an observatory. In the open field it can be arrived at approximately by a little practice in estimating the apparent distances in the sky, by some measuring line of the same kind, such as the constellation of the Plough (page 94).

Right Ascension is measured in hours from the first point of Aries. This point, or line, has no prominent star upon it, but it comes down from the pole through the great square of Pegasus, and very near the two stars forming the left hand side of the square.

Declination is measured from the equinoctial, upwards and downwards, in degrees; but here again there is no well defined line of stars to point out this circle, though there are some near it all the way round. The Polar distance can be taken instead, which is just the difference between the declination and ninety degrees.

Take the star Capella (Segment II., page 26), which has a right ascension of about five hours and a declination of about forty-five degrees. This can be roughly estimated by turning the hours into degrees ($15° = 1$ hour), and applying the Plough as a measuring line. Capella would be found two plough-lengths from the first point of Aries, and rather more than one plough-length from the Pole Star.

Another way of determining the position of a star is, celestial latitude or longitude ; but this has the disadvantage of the two starting points being unmarked in the sky by any object, viz., the pole of the ecliptic and the ecliptic itself (page 96). The pole of the ecliptic is twenty-three and a half degrees from the pole of the equinoctial, on the line of XVIII. hours Right Ascension, but it is difficult to locate, being in one of the coils of the Dragon. It is only by exact instruments that this mode of reckoning can be used, and that only for special purposes. It is generally avoided in ordinary use for another reason, that is, the danger of being confounded with terrestrial latitude and longitude, from which it is quite different.

A third way of designating the place of a star is by Altitude and Azimuth (page 96), but this is rather to find the bearings on the earth after the star has been located in some other way. The horizon and the zenith are the starting points of measurement, which are very useful at sea with the aid of the sextant, but as they are constantly changing with the position of the observer, they are unsuited for ready computation on land, and there are no catalogues drawn up on this principle. From the horizon to the zenith is ninety degrees—the full limit of Altitude, and Azimuth is measured right round the circle of the horizon. If a star has forty-five degrees of altitude, and forty-five degrees of Azimuth, it will be found by facing south-west and looking halfway up the sky ; but these figures would not do for the same star from any other point of view.

For all practical purposes in scouting the right ascension and declination given in the nautical almanac and all star catalogues, are the most readily available data, and are the easiest to apply off-hand, because the first point of Aries and the Pole Star once learned can never be forgotten, and their changes are the slowest movements known.

QUESTIONS AND EXERCISES.

Introduction (pages 9-13). — What are the two points in the heavens from which measurements are made? What is the rate of the precessional movement? In what constellation is the first point of Aries now situated? What is the sign of this point? Are the signs and the constellations the same? Adjust the dome to show the aspect of the heavens on 21st September at 9 p.m. and on the following morning at 3 a.m. Write out the Greek alphabet. Explain Right Ascension and Declination.

The Stars (15, 16).—What are the lengths in miles of the earth's radius—the astronomical unit—and the light year? At what rate per second does light travel? How many ancient constellations are there? What historical evidences prove the antiquity of the Zodiac?

North Circumpolar Stars (17-18).—What is a Circumpolar Star? Draw the series of concentric circles of the diagram (page 17) and mark in the hours, months and signs. Write out the names of the circumpolar constellations and some prominent stars near the boundary line.

Segment I. (19).—What star was the original first point of Aries? Name the principal stars in Cetus. What is the characteristic feature of Perseus? What remarkable star is in this constellation?

Segment II. (23-25).—Name the first magnitude stars in this segment. How many degrees is Capella distant from Menkalinan? What geometrical figure do the three "kids" form? What star is known as the eye of the Bull? What four stars distinguish Orion besides the belt? How many degrees does the belt measure? Name some other features of interest in Orion. How many Pleiades can be seen by the naked eye? How many can be seen through a telescope? What extra appendages does the camera bring out? Write out the names of the principal stars in the Pleiades. Repeat the rhyme which describes their disappearance below the horizon and their reappearance.

Segment III. (30, 31).—In what constellation is the higher solstitial point now situated? What three stars in this region of the sky form a large equilateral triangle? To what constellations do they belong? What distinguishes a true Binary star from one which only appears so in the line of sight? Describe the observed peculiarities of Sirius. What are the two ways of observing proper motion?

Segment IV. (35-37).—Name the seven principal stars in the Plough. What is the distinguishing feature of the Lion? What comet is associated with the November meteors? How is the earth protected from meteors? Name the periodic groups of meteors and their months. Describe the ending of Biela's comet. Do any meteors reach the earth?

Segment V. (41-43).—Name the two stars called the eyes of the Dragon. Name two first magnitude stars in this segment. What variable star is in the constellation of the Scales? Describe the movements of this star. Describe three different uses of the spectroscope. What are the two classes of prominences on the sun's edge? What proportion of heat radiated by the sun comes to the earth?

Segment VI. (47-49).—Describe the form and composition of the Northern Crown. Where is the lower solstitial point at present? What is the exact place of the Nebula in Lyra? What is its shape and size? How do the "lanes" as seen in the telescope appear on the photographic plate? How are the Nebulae classified?

Segment VII. (54, 55).—What are the characteristic features of Cepheus, Cygnus and Aquila? How many degrees do the Altair trio measure? What bright star is in Lyra? Describe the general appearance and position of the Milky Way. Whether do Nebulae or stars predominate in its composition? What was Herschell's suggestive comparison?

Segment VIII. (59-61).—What is the characteristic feature of Pegasus? Name its principal stars. Where is the present point of the Vernal Equinox? What three instruments are used to observe the stars "southing?" To what circle in the heavens does the transit instrument constantly point? What use is the "reticle" of the eye-piece? How many hours are shown on the dial of the astronomical clock? How are the beats of the

pendulum recorded? How is the transit of the star recorded? What are the different uses of the equatorial telescope and the transit instrument? How does the equatorial mounting counteract the effect of the earth's rotation? What accessories are adjusted to the eye-piece for special purposes? What is the principal use of the micrometer?

South Circumpolar Stars (65, 66).—What is observed in the rising and setting of the southern stars different from those in the northern hemisphere? In what direction is the Pole Star situated? In what constellation are the pointers? What is the Greek letter of the South Pole Star and in what constellation is it? How many stars of first magnitude does this part of the sky contain? Write down their names and constellations in order. What unique features are observed in the southern portion of the Milky Way? Describe the Magellanic Clouds.

Key to Umbrella Star Map (69).—How many degrees are in the circle? How many minutes in one degree? How many seconds in one minute? How are minutes and seconds of degrees distinguished from minutes and seconds of time? How many degrees are in a quadrant? How many degrees are marked by each of the thirty-two points of the compass?

The Solar System (75-78).—What are the evidences of a common origin in the members of the solar system?

The Outer Planets (78-82).—What are the evidences that the outer planets are not solid? Are the markings on Jupiter permanent? How many moons has it? How long have they been known and when was the last one discovered? Describe how the eclipses of Jupiter's moons are related to the velocity of light. What appendages has Saturn which makes it unique among the planets? Describe these severally, giving the dimensions in miles. How many moons has Saturn? What is the name, distance, and period of the outermost moon? Who was the discoverer of Uranus? What is its period of revolution round the sun? How many moons has Uranus and what is peculiar about their motions? Has Uranus any surface markings? When and how was Neptune discovered? What is its period of revolution and rate of motion in its orbit? How many moons has Neptune? How is the space occupied between the outer and inner planets?

The Minor Planets (82, 84).—What is the period and rate of motion of Mercury? Is Mercury as large as the earth? What is the effect upon the disc because of its orbit being between the earth and the sun? How near does Venus come to the earth? What is the proof that Venus has an atmosphere? What is the period and rate of motion of Venus? Of what importance are the transits of Venus? How far is Mars from the sun? What peculiarity is observed in its motion round its orbit? What are the proofs that Mars rotates on its axis? What kind of surface markings are observed on Mars? How many moons has Mars? What is the distance from the planet of the nearest moon, and how quickly does it go round?

The Earth, the Sun, and the Moon (84, 85).—What is the diameter of the earth? What is the angle of inclination of the poles? What is the rate of its revolution round the sun? In what constellation is the "Apex of the Sun's Way?" What is the probable rate of the sun in his orbit? What is the period of rotation on his axis? How is this known? In what direction is the moon's proper motion? How does the moon's velocity in her orbit work out—in one second—in one hour—in twenty-four hours—in relation to the diameter—in relation to a cannon ball—in relation to the planet Mercury?

Time (87-89).—What are the principal causes of unequal days? How and where is the equalizing adjustment made? Describe the three different kinds of time and their corresponding time-pieces. Describe the adjustment of the Julian calendar. What further adjustment was made in the Gregorian calendar? When was the change made from the Old Style to the New in the British Parliament? Describe the introduction of the Christian era.

Angular Measurement (94, 95).—What is meant by the angular distance of a body? What are the units of measurement? Name some ascertained degrees of distance in well-known constellations. What is a radian? What is its value in seconds of arc? What is the rule for computing apparent semi-diameter in relation to distance? Work out the apparent size of the moon's disc by simple proportion.

Azimuth and Altitude (96, 97).—How is the zenith point determined? What is the circle on the earth corresponding

with the zenith? What are the two co-ordinates associated with the zenith for locating the sun or a star? What is the difference between azimuth and amplitude? What is the difference between altitude and zenith distance? Draw the figure showing the place of a star by azimuth and altitude.

Right Ascension and Declination (98).—What is the distinction between the equator and the equinoctial? At what point does the equinoctial and the ecliptic intersect on 21st March? What are the two co-ordinates for finding a star by time and space? Draw the figure showing the place of a star by this system of observation.

The Vanishing Point (99).—What is the assumed limit in space which bounds all circles and converges all parallel lines? Draw the figure which shows this mathematical boundary.

Latitude (100, 101).—What is the rule for finding the latitude of the observer? How far is the Pole Star from the Pole? How is the actual polar point found? What instrument is used for this purpose? How much is a ray of light bent by refraction at the horizon? How much at the zenith?

Longitude (101, 102).—Describe how longitude is related to latitude. How is the circle of the equator divided? What is the equivalent in degrees to one hour of time? What instrument in Greenwich Observatory points to the standard meridian? How is Greenwich time obtained on board of a ship at sea?

A Ship at Sea (102).—When is the sextant observation made to obtain the sun's hour-angle? When is the sextant observation made to obtain the sun's altitude? How is the zenith distance found? How is the sun's declination obtained? What two factors combined give the latitude?

The Star Sphere (103).—How could the ancients make reliable observations when they did not know of the earth's rotation? What famous astronomer first advanced the theory of the earth rotating on its axis? What were his reasons?

Orbital Motion (105, 106).—How far does the earth travel in twenty-four hours? What constitutes siderial noon? How many minutes and seconds does it gain on Greenwich time—in a day—in a fortnight—in a month—in a year? How often does the earth pass the first point of Aries in a year?

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Testimonials.

ROYAL OBSERVATORY,
EDINBURGH, *21st January*, 1907.

MR. M'EWAN'S idea of representing the constellations on the inside of an umbrella seems to me an excellent one for giving a knowledge of the names and positions of the principal stars of demonstrating their movements. Owing to the use of watches, living in cities, and cloudy skies, practical acquaintance with the stars tends to become a somewhat rare accomplishment. Mr. M'Ewan's umbrella will give considerable assistance in making this acquaintance and should prove useful.

F. W. DYSON,
Astronomer Royal for Scotland.

THE OBSERVATORY,
GLASGOW, *10th July*, 1907.

MR. M'EWAN'S umbrella provides an easy method by which the principal stars and constellations can be identified and their positions predicted at all hours and seasons. The Umbrella Map is superior to ordinary star maps, and while it has some of the advantages of the celestial globe its portability and the fact that the observer can view the Umbrella Map and the heavens without looking in different directions make it even preferable to the celestial globe for the study of the constellations.

L. BECKER,
Professor of Astronomy in the University of Glasgow.

69 TYRWHITT ROAD,
ST. JOHN'S, LONDON, S.E., *9th August*, 1909.

So few persons comparatively are familiar with the stars, or take an interest in watching their nightly and yearly progress, that a device which will bring home to the general public, at one and the same time, the arrangement of the stars in the heavens, and their apparent movements, should meet with wide appreciation. Mr. M'Ewan's device of turning the inside of an umbrella into a portable star map, is at once so quaint and so ingenious, that it ought to take the popular fancy.

E. WALTER MAUNDER.

ROYAL OBSERVATORY,
EDINBURGH, *15th Jan.*, 1907.

HAVING had an opportunity of examining the "Celestial Umbrella," designed and completed with so much ingenuity by Mr. M'Ewan, it is my opinion that it will have much effect as a stimulus to the study of popular astronomy. By presenting to its owner a ready means of learning the configuration of the constellations, it will lead him to take a deeper interest in the stars.

An accompanying treatise gives simple directions for the use of the stellar umbrella, and contains a variety of information for the intelligent student. It is to be hoped that this interesting invention may attain a large circulation.

THOMAS HEATH,
Royal Observatory, Edinburgh.

THE COATS OBSERVATORY,
PAISLEY, *13th May*, 1907.

THE Star Umbrella seems to me to be an ingenious device and to be admirably suited as a good educational apparatus for imparting instruction in the elements of astronomy, a most attractive and truly educative subject which is too much neglected.

DONALD MACLEAN,
The Coats Observatory, Paisley.

E.U. MANSE,
BARRHEAD, *17th December*, 1906.

I HAVE watched with interest Mr. M'Ewan's development of his idea of using the interior of an umbrella as a star map, and I have examined several specimens of the completed article. They are remarkably correct, and owing to the concavity of the surface on which the stars are shown the map gives a better idea of the general relation of the constellation than can well be given on a flat surface. It is thus very easy to find the principal stars at the seasons when they are near the meridian, with the aid of the hour circle shown round the edge of the umbrella. The idea is a good one well wrought out and deserves success.

ED. BRUCE KIRK.

UNITED FREE HIGH MANSE,
PAISLEY, *4th Jan.*, 1907.

I HAVE taken a deep interest in Mr. M'Ewan's efforts to popularise the study of astronomy, and am greatly pleased with the umbrella he

has produced. Besides serving all the purposes of an ordinary umbrella it gives its possessor a complete map of the heavens, so that with a little "coaching" he is soon able to know the stars. With the "guide" which goes along with the umbrella, he can make rapid progress in this knowledge, so that the heavens above him at night would have a continual interest. Mr. M'Ewan deserves to be supported in this, his latest, endeavour to popularise astronomy.

J. B. STURROCK, M.A.

GLASGOW, *20th November*, 1907.

ASTRONOMY, more than any other subject, ought to be studied from the reality. But the reality is never available within school hours. Globes do in part supply the deficiency, but from a false point of view: other artificial aids are incomplete and costly. So it is hardly possible to bring out a real connection between the sky and the text book, and the knowledge gained is either hopelessly vague or repellently dry, and is soon forgotten. The umbrella supplies exactly what is wanted. It is a model sky, so far as it goes; and it goes far enough for all elementary study. The pupil sees what he reads of; sees it from the right point of view, and in the right relation.

This is the opinion of one who *knows* nothing of the science, but it is perhaps all the more valuable for that reason.

R. B. PATTIE, M.A., B.D.

ALBERT ROAD ACADEMY,
GLASGOW, *22nd November*, 1907.

I HAVE often thought that astronomy would be much more studied if we had a natural means of illustrating it. What we want is a globe such as was exhibited in Paris lately where the heavens could be viewed from the interior, the celestial globes and flat maps being little better than useless to convey a correct notion of astronomy.

Mr. M'Ewan has hit on a most simple and yet admirable substitute—the interior of an umbrella, which lends itself in a surprising manner to illustrate the essential points of interest. The stick of the umbrella forms a natural axis, and as the degrees are noted it is an easy matter to locate the constellations.

I showed this umbrella to a large advanced class studying astronomy, and they unanimously expressed their high appreciation of the appropriateness of the illustration and the facility with which it enabled them to verify in the open what they had studied in the class.

JOHN MAIN,
Lecturer on Natural Science.

Press Comments.

The Scotsman.—"A new Astronomical Map of a novel kind, prepared by Mr. D. M'Ewan, Member of the British Astronomical Association, will be of special utility for schools."

Weekly Scotsman.—"The interior of an ordinary umbrella gives a better idea of the constellations than a flat surface."

Glasgow Herald.—"At the Exhibition recently held at the Outlook Tower, Edinburgh, highest honours were awarded to Mr. D. M'Ewan for an Astronomical Umbrella."

Glasgow Weekly Herald.—"The Guide Book, which goes along with the Umbrella Star Map, contains a complete system of instruction in elementary astronomy for schools."

Glasgow Weekly Mail.—"It is easy to trace out the constellations and identify the principal stars in them, upon this novel and yet most convenient Star Atlas."

Edinburgh Evening News.—"With this novel contrivance the teacher can show the correct aspect of the heavens for any day or hour of the year, in the latitude of the British Isles, throughout the world."

Glasgow Evening Citizen.—"'The Umbrella' is a suitable apparatus, in conjunction with the Guide Book, for teaching astronomy to young persons."

Glasgow Evening Times.—"A novel and ingenious idea of constructing a map of the heavens."

Glasgow Weekly Record.—"The Map resembles the arch of the heavens, and gives a correct outline of the constellations."

Glasgow News.—"Astronomers have declared the stars to be correctly placed. This is the more remarkable, seeing that they had to be printed out of their true positions, so that each star would appear in its proper place when the Umbrella is put up."

Stirling Journal and Advertiser.—"Mr. M'Ewan has been, like Ferguson of old, a student of astronomy from his boyhood. His latest idea is to provide the public, and especially the schools, with a Star Map printed on the interior of an umbrella."

Stirling Observer.—"The Astronomical Umbrella is, to all appearance, an ordinary 'gamp' of the latest type. When put to its proper use as a shelter from the storm, few would observe anything unusual about it."

TELEGRAMS AND STATION } DRYMEN.

Buchanan Castle
Glasgow

Aug 7. 07.

Sir
I have had an opportunity of examining the umbella that you left me. It is a very ingenious contrivance for stimulating knowledge of the constellations & I hope it may lead to a deeper interest being taken in the stars.

Yr. Montrose

D. McEwen Esq.

Yerkes Observatory

Dec. 3d 1907

Wm. Hamilton Gibson

Roslyn, N.Y.

Dear Sir:

I have received your letter of Nov. 30th and am glad to know that you are interested in the matter of illustrating the seasons and stars by printing them on the inside of an umbrella. It should be very useful for schools.

Yours truly,

[signature]

Telephone Nos. { National, 1180 and 1181 HILLHEAD.
Post Office, W347.

THE UNIVERSITY,

GLASGOW, 7 Dec. 1907

Principal MacAlister thanks
Mr D McEwan for an
opportunity of seeing the
"celestial umbrella", &
congratulates him on
his application of a
new idea to the study
of the oldest of sciences.

Astron
M

115213

Author McEwan, D

Title An easy and concise guide to the starry heavens.

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